Transportation Energy Demand Analysis For Ontario

Vol. 1

Development of Forecast Methodology

Canadian Resourcecon Limited

Economic Consultants

Ontario

Ministry of Energy

(18)

Transportation Energy Demand Analysis for Ontario

Volume I : Development of Forecast Methodology

Final Report

prepared for the Ontario
Ministry of Energy

by

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NOTE TO THE READER

The complete report includes two volumes:

Volume I: Development of Forecast Methodology, which includes chapters I to V, pages 1 to 274.

Volume II: Base Case Forecast, which includes chapters VI to IX, pages 275 to 360.

Volume I is being released to aid other energy researchers. This report is under review within the Ministry of Energy. There are instances where, due to the limits on the resources available, relationships have been assumed which on a logical or a statistical basis are not entirely satisfactory. In this regard, the reader is advised to interpret and use the report carefully.

Volume II is intended only as an illustration of the model's ability to compute. To prevent possible misuse of these illustrative calculations the Ministry of Energy has decided not to release this document.

Refinements and extensions to this work are planned. The Ministry would appreciate any comments or suggestions from the reader.

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COMMENTS ON NOTATION

To avoid confusion the reader should note that all references to tables include the word "table", while references to source material have a similar format but comprise the number only. For example, "The GVW class proportions shown in Table III-26 may be used to develop rates of change over time (III-16)." The number III-16 designates the source as listed in the Bibliography.

Cross references between chapters of this report include Chapter and Section numbers. Cross references within chapters include the Section number only.

ENERGY CONVERSIONS

Unless specifically stated otherwise, all fuel and energy conversions are based on the energy equivalent factors printed in "Detailed Energy Supply and Demand in Canada" (Statistics Canada Catalogue 57-207). Relevant factors are summarized below.

Fuel type (quantity)	Energy content (000,000 Btu's)
Coal-imported bituminous (2,000 pounds)	25.8000
Motor gasoline (35 gallon barrel)	5.2220
Kerosene (35 gallon barrel)	5.6770
Diesel oil (35 gallon barrel)	5.8275
Light fuel oil (35 gallon barrel)	5.8275
Heavy fuel oil (35 gallon barrel)	6.2874
Aviation gasoline (35 gallon barrel)	5.0505
Aviation turbo fuel (35 gallon barrel)	5.4145
Natural gas (1000 cubic feet)	1.0000
Electricity (1,000 kilowatt hours)	3.4120

I INTRODUCTION

In early 1976 the Ontario Ministry of Energy commissioned three related research projects for the purpose of analyzing particular sectors of energy demand in the province. Each was to undertake an analysis of particular sectors of the provincial energy demand.

The purpose of each of these studies is described by the Ministry of Energy as:

> To develop analytic tools which will permit the determination of future energy demand by end use and fuel types in the Province of Ontario, under well stated assumptions concerning future socio-economic conditions, technological developments, and government policies.
>
> The emphasis of these three studies will be on the quantification of possible changes in future demand patterns, at a reasonable level of disaggregation by end use. The purpose is to understand the structure of energy demand rather than simple extrapolation of historic trends.

This report by Canadian Resourcecon deals with the analysis of energy use by the transportation sector in Ontario.

Study Objective

The objective of this transportation sector study is to establish relationships between explanatory variables and energy consumption in the transportation sector in Ontario which will enable long term (25 years) forecasts of energy consumption to be made. These forecasting models or methodologies should permit detailed analyses and projections to be made by end use and fuel type.

The transportation sector is to be disaggregated to the greatest extent practicable and forecast methodologies constructed for each of the individual transportation sub-categories (e.g. inter-city freight) or transportation modes (e.g. truck transport) which are identified. These forecasting models which are developed for each transportation sub-sector will permit the staff of the Ministry of Energy to develop projections of energy demand, by fuel type, for varying sets of economic, demographic, technological, fuel availability, and policy assumptions.

Though the primary study purpose is to construct forecasting models this report does present a 25 year forecast of energy demand, based on clearly defined scenarios, which is intended only to illustrate how the forecasting models can be operated.

The study procedure is to divide the transportation sector into logical sub-sectors, and to treat explicitly factors such as income, price, population, technology, spatial distribution, industrial activity, leisure time, communications technology, etc. in explaining transportation and energy demand in each of the sub-sectors defined.

It is clear that the development of sound forecasting models is a process which must be continued by Ministry of Energy personnel or others long after this specific study has been completed. The objective here is to identify, for each transportation sub-sector, the relationship between independent variables, the demand for transportation, and the resulting energy consumption; these relationships are quantified within the limits of available data. However, much of the quantification, and doubtless some improvement in the description of the underlying relationships themselves, will only be achieved at a later date as a result of data collection programs which will have to be instituted.

Consequently, a requirement of the study is an assessment of the adequacy of existing information systems and recommendations on further data collection programs.

Disaggregation of the Transportation Sector

The transportation sector has been divided into the following categories for the purpose of analysis.

Transportation Sub-Sector	Transportation Modes
Chapter II - Passenger Sectors	
Inter-City Passenger	- auto - air - bus - rail
Urban Passenger	- auto - public transit - taxi
Extraprovincial Passenger	- air
Chapter III - Freight Sectors	
Inter- City General Class Freight	- rail - truck - marine
Inter-City Specified Class Freight	- rail - marine - pipeline
Urban Truck : Freight and non-Freight	- truck

Chapter IV - Other Transportation Sectors

General Aviation	- air
Federal & Provincial Gov't Transportation (Including Military)	- air
Motorcycles	
School Buses	
Leisure Related Transportation	- snowmobiles
	- power boats

Procedures are developed for forecasting energy use by fuel type for each of these sub-categories of the transportation sector.

Study Methodology

In general the methodological approach presented in this analysis is to develop fuel use forecasting models in three steps as follows:

a) Develop models for forecasting total transportation demand for each sub-sector.

Relationships are developed between historical passenger-miles or ton-miles of output in Ontario and explanatory variables such as income measures, relative price trends, population growth (including age and geographical distribution), investments in infrastructure, etc. Models are formulated relating transportation output to these variables.

b) Develop models for forecasting <u>modal shares</u>.

Historical data on each mode's share of total demand in each transportation sub-sector is collected as, for example, the division of passenger miles of output among auto, air, rail, bus in the inter-city passenger sector. Data are assembled on such explanatory variables as relative infrastructure indexes, etc. and relationships developed between these factors and the demand for each mode providing transportation output. The total demand estimates produced by the transportation demand equations (in step (a) above), can then be broken down by mode based on the quantitative model relationships which are developed.

c) Develop models for forecasting energy use by mode and by fuel type.

Energy use efficiency values are developed in each transportation sub-sector for each mode in terms of Btu's per ton-mile or Btu's for passenger mile of output; these ratios are based on specific assumptions regarding load factors, technologies, operating procedures, etc. These energy efficiency values form the basis of forecasting future efficiency ratios which, when multiplied by the transportation output forecasts produced by the transportation demand and modal share models, yield forecasts of energy use by fuel type.

There are some exceptions to the use of the above approach. In the specified class freight category historical transportation demand and modal shares are not correlated with historical values of explanatory variables. Instead specific

forecasts of future movements in or through Ontario of such commodities as grain, coal, etc. are made and these multiplied by energy use per unit of output to determine future energy consumption levels. Also in sectors such as Urban Freight and Extra-Provincial Passenger, modal share equations are obviously not required as only a single mode is being considered.

Historical data regarding transportation output, as expected, were found to be of generally poor quality. This same observation applies to some of the explanatory variables which were tested; for example, expenditures on infrastructure or measures to describe such factors as service quality or industrial concentration; as a result much effort was expended estimating historical series. This is not to suggest, however, that the resulting figures are to be viewed as definitive. A considerable data collection program will have to be instituted if the reliability of the data is to be improved: recommendations where further work is required are summarized in Chapter V.

It is extremely important that this analysis be viewed only as a beginning: the Ministry of Energy must work towards the improvement of the forecasting models and the data series on a continuing basis if reliable forecasting tools are to be developed.

II PASSENGER SECTOR

General Introduction

The passenger sector has been disaggregated into three sub-sectors, inter-city passenger, urban passenger, and extraprovincial passenger. The reason for disaggregating passenger travel lies in the distinction of travel purpose in each of these markets and/or in the different array of competing modes which operates in each market; analyzing passenger demand by sub-sector then allows more precision in the identification of factors affecting each demand function and allows for a more careful consideration of inter-modal choice. For example in the case of the urban passenger sub-sector much of the travel is work or shopping related and transit modes and taxi offer alternatives to the automobile; in the case of the inter-city market within Ontario,travel is mainly associated with leisure travel or longer business trips and the choice of mode facing the traveller includes auto, airplane, bus, and train.

Twenty years of historical data on transportation demand, and variables thought to influence transportation demand and modal choice, have been developed for each of the three sub-sectors. These data series form the basis of establishing the transportation demand and modal share models used to forecast transportation output by mode. Energy use models are also developed for each mode in each passenger market; this enables the fuel use effects of a range of technology or policy variables to be tested. Multiplying the transportation output figures by fuel use efficiency ratios then enables energy use forecasts by fuel type to be produced.

A. INTER-CITY PASSENGER

1. Introduction

Inter-city passenger travel is generally defined as travel outside the urban setting characterized by longer trips where, in most cases, the competing modes are auto, airplane, bus, and train. In this analysis it is defined as travel between Ontario's Census Metropolitan Areas (CMA's), between CMA's and other centres, or more generally any passenger travel outside of CMA's (to the extent that this can be defined and determined). It should be recognized that the geographical distinction between inter-city and urban travel is in many cases not definitionally a clear one, and consistency of definitions from one mode to the other between what constitutes inter-city travel and urban travel is difficult to maintain.

For the automobile mode inter-city travel is typified by trips of greater than 20 miles at constant speeds with only a small amount of stop and go driving, and the auto operating under a "warmed-up" driving condition. Inter-city air passenger mile estimates include trips between Ontario points only except for the inclusion of the Ottawa-Montreal and Toronto-Montreal routings; the Ontario "in air" portions of extraprovincial flights are not included in this Ontario inter-city category. Bus and train passenger mile output is defined as all inter-city passenger travel within Ontario boundaries.

2. Transportation Demand

2.1 Historical Transportation Output

(a) Transportation Output - Automobile

Table II-1 summarizes the calculated inter-city and urban passenger miles by the automobile mode for Ontario for the period 1955-1974.

Vehicle miles of inter-city and urban auto travel over this historical period are also shown in Table II-1. Inter-city passenger miles are derived from the vehicle mile figures assuming a load factor of 2.4 passenger miles per vehicle mile (II-1, 816).

Total inter-city automobile vehicle miles have increased about 2.3 times over the period 1955 to 1974, having grown at an average annual rate of 4.5% per year (Table II-1). Inter-city vehicle miles are estimated to have declined from 46.2 percent of total automobile vehicle miles to 43.0 percent in 1971; since 1971 the trend has reversed with the inter-city proportion of the total growing somewhat to reflect a slight decline in the proportion of Ontario residents living in census metropolitan areas (Table II-2). These figures compare to U.S. estimates that 45 percent of all automobile traffic is inter-city in nature and 55 percent is urban (II-1, p.816, Table 1).

TABLE II-1

INTER-CITY PASSENGER MILES BY THE AUTOMOBILE MODE: 1955-1974

Year	Pass. Autos Ontario Registrations (000)	Average Miles Per Registered Vehicles	Total Vehicle Miles (000,000)	Vehicle Miles Urban %	Vehicle Miles Urban (000,000)	Vehicle Miles Inter-City %	Vehicle Miles Inter-City (000,000)	Passenger Miles Urban (000,000)	Passenger Miles Inter-City (000,000)
	(1)	(2)	(3)		(4)		(5)	(6)	(7)
1955	1,305	9,359	11,993	53.8	6,452	46.2	5,541	12,259	13,298
1956	1,387	9,348	12,739	54.2	6,905	45.8	5,834	13,119	14,002
1957	1,462	9,391	13,492	54.0	7,286	46.0	6,206	13,691	14,894
1958	1,534	9,494	14,316	54.1	7,745	45.9	6,571	14,715	15,770
1959	1,631	9,529	15,286	54.4	8,316	45.6	6,970	15,800	16,728
1960	1,716	9,446	15,946	54.6	8,707	45.4	7,239	16,543	17,374
1961	1,776	9,465	16,540	55.1	9,114	44.9	7,426	17,317	17,822
1962	1,822	9,441	16,924	55.5	9,393	44.5	7,531	17,847	18,074
1963	1,908	9,240	17,346	55.8	9,679	44.2	7,667	18,390	18,401
1964	2,009	9,286	18,363	56.0	10,283	44.0	8,080	19,538	19,392
1965	2,119	9,387	19,589	56.2	11,009	43.8	8,580	20,917	20,592
1966	2,213	9,506	20,723	56.3	11,667	43.7	9,056	22,167	21,734
1967	2,289	9,531	21,492	56.5	12,143	43.5	9,349	23,072	22,438
1968	2,401	9,627	22,782	56.7	12,197	43.3	9,865	23,174	23,676
1969	2,477	9,782	23,890	56.9	13,593	43.1	10,297	25,827	24,713
1970	2,550	9,978	25,096	57.0	14,305	43.0	10,791	27,179	25,898
1971	2,686	10,121	26,830	57.0	15,293	43.0	11,537	29,057	27,689
1972	2,821	10,184	28,368	57.0	16,170	43.0	12,198	30,723	29,275
1973	2,972	9,992	29,333	56.8	16,661	43.2	12,672	31,656	30,413
1974	3,222	9,300	29,597	56.6	16,752	43.4	12,845	31,829	30,828

FOOTNOTES: See next page.

FOOTNOTES TO TABLE II-1

Column 1:

Ontario auto registrations for years running from March 1 to February 28 were compiled from Statistics Canada data, SC53-219. Totals include taxis and U-drive. SC totals were reduced by 1 percent to account for replacement registrations due to lost plates.

Column 2:

Average total number of miles travelled each year per passenger vehicle (including taxis) is based on U.S.A. Federal Highway Administration estimates as reported in 1975 Automobile Facts and Figures, p. 46, for the years 1963 to 1973 inclusive, and in 1967 Automobile Facts and Figures, p.44, for the years 1955 to 1962. Figure for 1974 is based on estimate of U.S. Motor Vehicle Manufacturers Association of average miles per vehicle for all motor vehicles of 9,360 miles, p.46, 1975 Automobile Facts and Figures.

Column 3:

Total vehicle miles travelled in Ontario each year are calculated by multiplying Column 2 x Column 1 and deducting taxi vehicle miles (Table II-27).

Columns 4 and 5:

The percentage of total automobile vehicle miles travelled in each of the Inter-City and Urban sectors was calculated as follows:

Auto ownership is assumed equal on a per capita basis in urban and non-urban areas and vehicle miles per auto per year are assumed the same whether a vehicle is based in an urban or non-urban area.

Urban residents are assumed to drive 75 percent of total vehicle miles in urban areas and 25 percent of vehicle miles in Inter-City driving.

Non-urban residents are assumed to drive in urban areas for 25 percent of total vehicle miles and in Inter-City travel for 75 percent of total vehicle miles.

The population of Ontario was divided into urban and non-urban areas, urban areas being defined as those with populations greater than 100,000 in 1974 (see Table II-2). The proportion of the Ontario population living in urban areas each year was calculated.

FOOTNOTES TO TABLE II-1

The proportion of Urban and Inter-City vehicle miles travelled each year was calculated as follows using 1956 by way of example:

$$\text{Urban VMT} = 75\% \times \text{VMT urban drivers} + 25\% \text{ VMT non-urban drivers}$$
$$= 75\% \times \frac{\text{urban drivers}}{\text{total drivers}} \times \text{total VMT} + 25\% \times \frac{\text{non-urban drivers}}{\text{total drivers}} \times \text{total VMT}$$

$$\text{Urban VMT (1956)} = 75\% \times 58.3\% \times \text{VMT} + 25\% \times 41.7\% \times \text{VMT}$$
$$= \text{VMT } (75\% \times 58.3\% + 25\% \times 41.7\%)$$
$$= \text{VMT } (43.7 + 10.5) = \underline{\text{Total VMT} \times 54.2\%}$$

$$\text{Inter-City VMT (1956)} = \text{Total VMT } (100\% - 54.2\%) = \underline{\text{Total VMT} \times 45.8\%}$$

Urban and Inter-City passenger miles for each year were calculated by multiplying the total VMT figure for the year by the calculated percentages of urban and inter-city driving.

Column 6:

Urban passenger miles were developed by multiplying urban vehicle miles for each year by an assumed average load factor for urban driving of 1.9 passenger miles per vehicle mile. The average load factor of 1.9 passenger miles per vehicle mile is related to the following trip purpose information (II-1, 816).

Trip purpose	*Average occupancy per trip*	*Percentage of total trips*
journey to work	1.4	37.1
family business (medical, shopping, etc.)	1.9	31.1
educational, civic and religious	2.5	9.2
social and recreational	2.6	22.6
		100.0

Column 7:

Inter-city passenger miles were developed by multiplying inter-city vehcile miles for each year by an assumed average load factor for inter-city driving of 2.4 passenger miles per vehicle mile (II-1, 816).

TABLE II-2

ONTARIO URBAN/NON-URBAN POPULATION SPLIT 1955 TO 1974

	POPULATION [2]											
Year	Ontario [1]	Hamilton	Kitchener	London	Ottawa [3]	St.Catherine's-Niagara	Sudbury	Thunder Bay	Toronto	Windsor	Total Urban [4]	Percent Urban
1955	5,266	na	na	na	na	na	na	na	na	na	3,030	57.5
1956	5,405	342	129	196	276	233	108	87	1,572	208	3,151	58.3
1957	5,636	na	na	na	na	na	na	na	na	na	3,270	58.0
1958	5,821	na	na	na	na	na	na	na	na	na	3,390	58.2
1959	5,969	na	na	na	na	na	na	na	na	na	3,510	58.8
1960	6,111	na	na	na	na	na	na	na	na	na	3,625	59.3
1961	6,236	401	155	227	343	258	127	102	1,919	217	3,749	60.1
1962	6,351	na	na	na	na	na	na	na	na	na	3,870	60.9
1963	6,481	na	na	na	na	na	na	na	na	na	3,990	61.6
1964	6,631	na	na	na	na	na	na	na	na	na	4,110	62.0
1965	6,788	na	na	na	na	na	na	na	na	na	4,235	62.4
1966	6,961	457	192	254	398	285	137	108	2,290	238	4,359	62.6
1967	7,127	471	199	263	410	289	140	109	2,366	243	4,490	63.0
1968	7,262	480	206	270	421	293	144	110	2,435	248	4,607	63.4
1969	7,385	488	213	276	431	296	148	110	2,495	252	4,709	63.8
1970	7,551	494	221	281	442	300	152	111	2,567	255	4,823	63.9
1971	7,703	499	227	286	453	303	155	112	2,628	259	4,922	63.9
1972	7,824	505	232	290	460	307	157	113	2,672	262	4,998	63.9
1973	7,939	513	235	293	464	308	155	113	2,692	264	5,037	63.5
1974	8,094	520	238	296	470	311	154	112	2,741	266	5,108	63.1

FOOTNOTES: See next page.

Footnotes to Table II-2

(1) Ontario population SC 91-201.

(2) Population of Census Metropolitan Area from SC 91-207 except for 1956 from Canada Year Book, 1973, p. 211.

(3) Ottawa population estimated at 75 percent of Ottawa-Hull CMA population for all years. This is the proportion which applied in 1966 and 1971 from SC 92-708 Volume 1, Part 1 (Bulletin 1.1 - 8), 1971 Census of Canada.

(4) Total urban population for the years 1957 to 1960 and 1962 to 1965 obtained by graphical interpolation.

(b) Transportation Output - Air

Published air passenger statistics do not provide measures of passenger mile output on a provincial basis. The objective here is to compile an historical passenger mile series for the air mode which reflects inter-city air passenger movements between points within Ontario as well as passenger miles attributable to the Ottawa-Montreal and Toronto-Montreal routings.

To satisfy the data requirements of the model two options were available: one was to make a special request to the Aviation Statistics Centre of Statistics Canada for the data required; the second involved using the data that were available in published form and tailoring it to fit the Ontario situation. Having discussed with the Aviation Statistics Centre the data requirements of this study, it was concluded that to provide data in the form required in this analysis would be a very expensive undertaking. It was therefore decided that readily available published data would be used to a large extent, and that data which could be provided on a special request basis from Statistics Canada would be used as a supplement subject to the time and budget constraints of the study.

The air passenger mile figures for Ontario which appear in Table II-3 have been compiled using two basic information sources published by Statistics Canada: Air Carrier Operations in Canada (SC 51-002) formerly Civil Aviation (SC 51-001) and Air Passenger Origin and Destination-Domestic Report (SC 51-204).

TABLE II-3

INTER-CITY PASSENGER MILES BY THE AIR MODE, ONTARIO, 1955-1974

(000,000 passenger miles)

Year	Unit Toll Service			Charter Service		Total Passenger Miles
	Canada (1)	Ontario (2)		Canada (3)	Ontario (4)	
		O/D Study	ASC Based			
1955	1,193	85	133	48	5	138
1956	1,507	107	167	88	10	177
1957	1,820	129	202	129	14	216
1958	2,134	152	238	169	19	257
1959	2,456	174	272	210	23	300
1960	2,671	190	297	253	28	325
1961	3,157	247	386	300	37	423
1962	3,464	261	408	328	39	447
1963	3,628	268	419	344	40	459
1964	3,924	273	427	433	47	474
1965	4,728	311	486	427	44	530
1966	5,604	336	525	464	43	568
1967	6,935	409	639	392	36	675
1968	7,525	424	663	646	57	720
1969	8,174	458	716	1,166	102	818
1970	9,638	551	861	1,916	171	1,032
1971	9,564	573	883	1,914	177	1,060
1972	11,489	630	984	2,010	172	1,156
1973	13,599	761	1,189	2,483	217	1,406
1974	15,395	821	1,304	2,717	230	1,534

FOOTNOTES: see next page.

FOOTNOTES TO TABLE II-3

(1) *This series was compiled from SC 51-002 Air Carrier Operations in Canada for the years 1970 through 1974 and from SC 51-001 Civil Aviation for 1959 through 1969 and reflects passenger miles accounted for by domestic airlines providing scheduled unit toll service on domestic and international routes. Passenger mile statistics for the years 1955 to 1958 were linearly extrapolated from 1959 to 1969 data.*

(2) *Measures of passenger mile output were compiled for the years 1968 to 1974 from the Domestic Air Passenger Origin and Destination Report (SC 51-204). Estimates of the number of persons travelling between city pairs within Ontario plus traffic on the Ottawa-Montreal and Toronto-Montreal routings were obtained from the O/D studies. The number of passengers travelling between city pairs was multiplied by the air distance between the city pairs to derive an estimate of passenger miles. These figures were then totalled for the 100 or so city pairs identified. A supplementary aspect of this analysis involved compiling passenger mile estimates for the domestic (intra Ontario) portions of international journeys; the basic information on passenger traffic was obtained from the O/D reports and passenger mile estimates were prepared using the methodology outlined above.*

As time restrictions did not permit the analysis of O/D studies for years prior to 1968, it was necessary to adopt a method to enable the derivation of passenger mile information for earlier years. The passenger mile estimates developed for Ontario for the period 1968 through 1974 were compared with air passenger mile output totals for Canada. It was found that the proportional relationship, Ontario passenger miles to Canadian passenger miles, was reasonably stable, at an average value of 5.6 percent; this measure was applied to the Canadian passenger mile totals for those years prior to 1968.

Finally, the O/D based figures were adjusted upwards based on special tabulations for 1971 and 1974 prepared by the Aviation Statistics Centre in Ottawa. The ASC compiled passenger mile totals for routes within Ontario served by Air Canada, Transair, and Nordair (1971 and 1974) and Level III and IV carriers (1974 only); a 1971 estimate of Level III and IV carrier passenger miles was calculated based on the 1974 proportion of Level III and IV output to Level I and II. The ASC figure for 1974 is 1304 million passenger miles and for 1971 is 883 million passenger miles. For each of these two years the ASC total is in the order of 1.56 of the O/D based total; therefore this factor was used to adjust the O/D passenger-mile estimates upwards for all the years from 1955 to 1974.

The ASC based totals for unit toll service in Ontario still underestimates the total of Ontario flights; not included in the ASC figures are the Ontario portions of transcontinental or international flights (for example the Ottawa-Toronto portion of an Ottawa-Toronto-Vancouver flight is not included in the ASC compilations).

FOOTNOTES TO TABLE II-3 CONTINUED

(3) *Air charter passenger miles for Canada were complied from Statistics Canada reports 51-002 and 51-001.*

(4) *The Ontario share of total Canadian air passenger miles accounted for by charter activity was computed using the proportional relationships derived for unit toll service. It is implicitly assumed that the Ontario share of charter passenger miles (i.e., charter activity between points within Ontario) is equivalent to the Ontario share of Canadian passenger miles related to unit toll service.*

(c) Transportation Output - Bus

As for the other inter-city passenger modes, it has been necessary to derive an historical passenger mile series for inter-city bus. The data base in its present form has been developed largely from statistics compiled by the Ontario Ministry of Transportation and Communications. The statistics relate to seat mile tax revenue collected from bus companies operating within Ontario. Seat mile tax revenue has been converted to gross seat miles and in turn to passenger miles. The assumptions used to perform these operations are specified in the footnotes in Table II-4.

School bus output statistics have not been calculated and are not included in the bus output totals presented here.

TABLE II-4

INTER-CITY PASSENGER MILES BY THE BUS MODE, 1955-1974

Year	Seat Mile Tax Revenue (1)	Seat Miles (2)	Total Passenger Miles (3)
	$	(000,000)	(000,000)
1955	426,158	1,027	472
1956	427,202	1,029	473
1957	432,268	1,042	479
1958	425,305	1,025	471
1959	436,459	1,052	484
1960	415,483	1,001	460
1961	426,458	1,028	473
1962	447,485	1,078	496
1963	453,350	1,213	558
1964	357,451	1,430	657
1965	326,449	1,306	601
1966	371,243	1,485	683
1967	470,832	1,883	866
1968	433,518	1,734	798
1969	434,138	1,737	799
1970	452,081	1,808	832
1971	496,951	1,988	914
1972	na	na	840 est.
1973	na	na	850 est.
1974	na	na	863

FOOTNOTES: see next page.

FOOTNOTES TO TABLE II-4

(1) *Seat mile tax revenue statistics were obtained from the Vehicle Branch of the Ministry of Transportation and Communication. Collection of this tax was terminated in 1972.*

(2) *Gross seat miles were derived by dividing the seat mile tax revenue by the tax per seat mile. For the period 1964 to 1971 the seat mile tax was .02¢/seat mile on class B highways and .03¢/seat mile on class A highways. Prior to 1964 the tax was .033¢/seat mile on class B highways and .05¢/seat mile on class A highways. It has been assumed that seat miles attributable to bus travel on class A and B highways are equivalent. Further investigation will be necessary to check the validity of this assumption.*

(3) *To derive passenger mile output figures from seat miles necessitated the introduction of passenger load factors. A preliminary load factor estimate was generated using information contained in a recent CTC study (Intercity Passenger Transport in Canada: A Review of the Existing Intercity Passenger Transport Systems). CTC researchers found that average revenue per bus mile was 91 cents and the average fare per bus mile was 4 to 5 cents, say 4.5 cents; therefore, the average number of passengers per bus mile is 20.5. Information on bus seating capacity published in Statistics Canada publication 53-215 (Passenger Bus Statistics) indicates that as of 1970 median seating capacity was on the order of 40 to 49 seats per bus, say 45. If the capacity is 45 and the number of passengers approximately 20-21, then the load factor is around 46 percent. This load factor has been applied to the series of gross seat mile figures to obtain passenger mile estimates. This load factor estimate is supported by recent Ontario MTC estimates; MTC estimate the major carriers, who account for nearly 85 percent of total vehicle miles in Ontario, operate at load factors in the 42 to 56 percent range (II-2).*

The passenger mile total for 1974 is bases on data provided by MTC (II-2) as follows:

Carrier Group	Annual VMT's (000)	Average Passengers	Passenger Miles (000,000)
Local	4,895	8	39
Regional	2,006	12	24
Major	36,377	22	800
		Total	Total 863

The 1972 and 1973 totals are estimated by Resourcecon at slightly less than the 1974 figure.

(d) Transportation Output - Rail

Rail passenger statistics (e.g. passenger miles) are published on an individual basis for the largest railways and on an aggregate basis for all railways in Canada. To the extent that a railway operates solely within one province, it is possible to identify the magnitude of rail passenger activity at the provincial level. Otherwise no breakdown of rail passenger miles provincially is provided. This problem is particularly important with respect to the two transcontinental carriers. Both Canadian National and Canadian Pacific were approached and requested to provide information on the extent of their operations within Ontario; the CNR did provide some Ontario specific passenger mile data for the years 1970 and 1971. Both railways could provide estimates of their Ontario passenger traffic over a long term historical period but the exercise would be time consuming and they would wish to be remunerated.

Two reports published by Statistics Canada, Railway Operating Statistics (SC 52-003) and Railway Transport: Part IV (SC 52-210), and a Ministry of Transport study on rail passenger services have been the primary sources used for the preparation of the historical data base for the inter-city rail passenger sector shown in Table II-5.

TABLE II-5

INTER-CITY PASSENGER MILES BY THE RAIL MODE, ONTARIO, 1955-74

Year	Canadian National(1)	Canadian Pacific(1)	Other Railways(2)	Total Passenger Miles Ontario
		(000,000 passenger miles)		
1955	690	534	175	1,399
1956	710	525	173	1,408
1957	715	537	143	1,395
1958	602	461	119	1,182
1959	606	446	109	1,161
1960	572	404	105	1,081
1961	514	336	91	941
1962	540	339	90	969
1963	573	337	80	990
1964	791	410	84	1,285
1965	861	352	79	1,292
1966	992	223	73	1,288
1967	1,246	251	56	1,553
1968	1,018	198	53	1,269
1969	911	194	54	1,159
1970	867	171	52	1,090
1971	851	151	53	1,055
1972	791	136	63	990
1973	611	99	62	772
1974	688	140	66	894

FOOTNOTES: see next page

FOOTNOTES TO TABLE II-5

(1) *A report prepared by the Ministry of Transport (A Report on Canadian Passenger Rail Services) provides an analysis of the number of passengers and passenger miles reported by CN and CP for rail passenger routes. This information is available for 1972 and 1974. The study identifies a number of routes which are totally within Ontario; other routes are only partially within Ontario,for instance, the trans-continental service. For those services between points within Ontario, the passenger mile figures reported can be ascribed totally to Ontario. For those rail services only partially within Ontario, passenger mile figures have been prorated on the basis of the proportion of total route mileage within Ontario; i.e.*

$$\text{Ontario passenger miles} = \frac{\text{route mileage within Ontario}}{\text{total route mileage}} \times \text{passenger miles reported for route}$$

Passenger mile estimates reflecting the operations of each railway within Ontario have been prepared and expressed as a proportion of total national passenger miles for each railway for 1972 and 1974. For CN, Ontario passenger miles represent 49 and 54 per cent of total CN passenger miles for 1972 and 1974 respectively; the comparable percentage values for CP for 1972 and 1974 are 39 and 41 per cent. The percentage values obtained for each railway have been averaged and the result applied to the national passenger mile output figures for CP and CN for all other years in the series. National passenger mile figures for CN and CP came from SC 52-003.

Both the CPR and CNR were requested to provide passenger output information for Ontario. The CPR did not provide any data. The CNR provided figures for the years 1970 and 1971; their estimates are lower than those presented in this table; their 1970 figure was 711 million passenger miles and the 1971 figure was 675 million.

(2) *Passenger mile figures for all other railways providing passenger service within Ontario were obtained from SC 53-210. Railways comprising this other category include: Ontario Northland, Algoma Central, Canada Southern, Toronto, Hamilton, Buffalo and others.*

(e) Transportation Output - All Modes

Table II-6 summarizes inter-city passenger mile output by mode for Ontario for the period 1955 to 1974. During the period, transportation output has grown from 15 billion passenger miles to over 34 billion passenger miles, an average annual increase of 4.4 percent. The automobile is predominant - it has accounted for approximately 90 percent of all inter-city passenger travel over the whole of the historical period. On a modal basis inter-city passenger mile output has increased by a factor of 2.6 for the automobile, 13 for the airplane and 2 for the bus mode; inter-city rail passenger output has declined.

TABLE II-6

INTER-CITY PASSENGER OUTPUT, ONTARIO, 1955-1974

(000,000 passenger miles)

Year	Automobile		Air		Bus		Rail		Total
	PM	% Total	PM	% Total	PM	% Total	PM	% Total	PM
1955	13,298	86.9	138	0.9	472	3.1	1,399	9.1	15,307
1956	14,002	87.2	177	1.1	473	3.0	1,408	8.7	16,060
1957	14,894	87.7	216	1.3	479	2.8	1,395	8.2	16,984
1958	15,770	89.2	257	1.5	471	2.7	1,182	6.6	17,680
1959	16,728	89.6	300	1.6	484	2.6	1,161	6.2	18,673
1960	17,374	90.3	325	1.7	460	2.4	1,081	5.6	19,240
1961	17,822	90.7	423	2.1	473	2.4	941	4.8	19,659
1962	18,074	90.4	447	2.2	496	2.5	969	4.9	19,986
1963	18,401	90.2	459	2.2	558	2.7	990	4.9	20,408
1964	19,392	88.9	474	2.2	657	3.0	1,285	5.9	21,808
1965	20,592	89.5	530	2.3	601	2.6	1,292	5.6	23,015
1966	21,734	89.5	568	2.3	683	2.8	1,288	5.4	24,273
1967	22,438	88.0	675	2.6	866	3.4	1,533	6.0	25,512
1968	23,676	89.5	720	2.7	798	3.0	1,269	4.8	26,463
1969	24,713	89.9	818	3.0	799	2.9	1,159	4.2	27,489
1970	25,898	89.8	1,032	3.6	832	2.9	1,090	3.7	28,852
1971	27,689	90.7	1,060	3.5	914	3.0	1,055	3.4	30,718
1972	29,275	90.7	1,156	3.6	840	2.6	990	3.1	32,261
1973	30,413	91.0	1,406	4.2	850	2.5	772	2.3	33,441
1974	30,828	90.4	1,534	4.5	863	2.5	894	2.6	34,119

SOURCE: Tables II-1, II-3, II-4, and II-5.

2.2 Explanatory Variables

The models which have been developed to describe each of the transportation sectors studied represent the end product of a succession of compromises between conflicting goals. Although it is the inter-city passenger category which is considered here, the argument holds true for all categories. On the one hand, the intention is to explain the historical variation in the dependent variable as fully as possible. As a result, output figures over the past 20 years have been analyzed, and in each instance time series of a number of independent (explanatory) variables have been developed which seek to explain historical changes in output. On the other hand, the modelling procedure was undertaken in light of two necessarily stringent limitations. First, for all variables which were chosen, reliable and quantifiable information had to be available (or capable of being developed) not only for the past 20 years but also for 25 years into the future. Secondly, to be useful and easily workable, a model of the sort requested here must not rely upon too large a number of independent variables. The limits are set by both the rules of econometrics and by intuition: if a modelling procedure, which is intended to clarify a situation by isolating certain significant relationships among various activities, instead concludes that the complex interaction of 15 or 20 factors must be analyzed in order to forecast future demands for the mode or sector, then little assistance has been rendered.

The goal, then, was to develop accurate and defensible models for each sector which would prove relatively fast and easy to use and which would not require large additional expenditures (of time or money) in order to complete or

maintain data requirements. The models which follow, therefore, do not represent the last word in sophisticated forecasting techniques. But their results provide important assistance in determining the interaction of a number of principal economic and social parameters, and suggest that a generally high degree of confidence can be placed in the resultant forecasts.

Following is a brief discussion of the major variables which have been utilized in attempts to describe transportation demand in the inter-city passenger market (Table II-7):*

(i) Per-capita personal income, Ontario (PCY) was obtained from Ontario Statistics (OS), Vol. II, Table 11.6

(ii) Population (POP) of Ontario was obtained on an annual basis from OS, Table 2.1.

(iii) Urbanization ratio (URB) presents a measure of the percent of Ontario's population that lives in the CMA's and was obtained from OS, Table 2.11.

(iv) Population characteristics (PCH) was derived using annual information which showed the change in the relative percentage of the population which would be most prone to engage in inter-city travel; this was estimated to be that segment of Ontario's population between 16 and 64 years of age (OS, Table 2.9).

(v) Communications index (COM) was included because of a belief that the increased use of communications facilities represents to some extent a substitute for increases

* *Note that both "scale" variables (such as population) and "characteristic variables" (such as the urbanization index) have been attempted, as is common in transport demand studies. See Richard E. Quandt and William J. Baumol, "The Demand for Abstract Transport Modes: Theory and Measurement," Journal of Regional Science, 6 (1966), pp. 13-26.*

TABLE II-7

INDEPENDENT VARIABLES - TRANSPORTATION DEMAND,
INTER-CITY PASSENGER

Year	(1) URB	(2) PCY	(3) PCH	(4) POP	(5) COM
	%	$	%	'000	'000,000
1955	59.6	1,619	62.1	5,266	52.8
1956	60.0	1,724	61.0	5,405	63.6
1957	60.4	1,812	61.3	5,636	67.2
1958	60.8	1,856	60.8	5,821	72.6
1959	61.2	1,911	60.4	5,969	76.6
1960	61.6	1,951	60.1	6,111	80.2
1961	61.9	1,954	59.7	6,236	85.6
1962	62.3	2,062	59.5	6,351	92.1
1963	62.7	2,156	59.4	6,481	48.1
1964	63.1	2,267	59.6	6.631	104.8
1965	63.5	2,436	59.8	6,788	112.1
1966	64.6	2,680	60.2	6,961	119.0
1966	64.9	2,884	60.7	7,124	132.3
1968	65.3	3,146	61.3	7,262	143.3
1969	65.9	3,470	61.8	7,385	162.3
1970	65.8	3,705	62.4	7,551	169.0
1971	65.8	3,991	63.0	7,703	181.8
1972	65.8	4,366	63.5	7,834	211.3
1973	65.4	4,840	64.2	7,939	238.9
1974	65.0	5,572	64.9	8,094	271.4

(1) Urbanization index.

(2) Per-capita personal income, Ontario.

(3) Population characteristics.

(4) Population of Ontario, total.

(5) Communications index.

in the demand for transportation. The specific variable examined shows the annual number of non-local telephone calls made in Ontario (SC 56-203) and was derived from available pooled Quebec-Ontario information on the basis of their yearly population share.

2.3 Forecasting Model

(a) Introduction

This section discusses the form of the model which has been developed, and presents some preliminary remarks regarding the interpretation of these results. Both one and two stage least squares estimation procedures have been attempted; the one-stage model which is presented appears to successfully explain most of the annual variation in the demand for inter-city passenger transportation while utilizing an easily manageable set of variables. The results of this model are shown in Table II-8; a short discussion of the findings, as well as a brief, non-rigorous interpretation of the important test statistics which are utilized, is given below.

(b) Discussion of Results

The transportation demand equation which has been selected seeks to explain changes in total inter-city passenger miles travelled by all modes from 1955-74 on the basis of the variation in per-capita income and in population. For both coefficients the signs are as would be expected, and thus the model appears to behave in a manner consistent with intuition and experience.

TABLE II-8

INITIAL REGRESSION MODEL: INTER-CITY PASSENGER

General Form of the Basic Demand Model:

TRD = f (PCY, POP)

where

TRD = inter-city passenger transportation demand (in passenger miles)

PCY = per-capita personal income, Ontario

POP = population of Ontario, total

Basic Equations:

$$TRD = a_0 + a_1 (PCY)_t + a_2 (POP)_t$$

a_0	a_1	a_2
- 9992.7	2.18	4.08
(-6.60)	(9.18)**	(12.98)**

R = .995

F = 1728

DW = 1.13

** *Significant at the .05 level.*

The t-statistic, which tests the probability that the coefficient which is derived could in fact be equal to, or greater than, the value which is estimated by the regression equation if the true coefficient were zero, provides an indication of the importance which can be placed on the explanatory value of a variable. The t-distribution itself, with mean of zero, approaches the standard normal distribution as the size of the sample increases.

In this case, to be significant at the 10 percent level, (for a one-tailed test)* the t-statistic must equal 1.33 (which means that a value - calculated from a sample of 20 - which exceeds 1.33 would occur with a probability of 0.10); to be signficant at the 5 percent level it must equal 1.74. Thus, for example, the highly significant test statistic of 9.18 on per-capita personal income indicates that a high degree of confidence can be placed on the effect of changes in this factor on transportation demand, whereas an insignificant t-statistic of (for example) 1.1 would tend to cast doubt of the existence of a strong relationship between the variable and transportation demand. The range of t-statistics which is derived therefore reflects the differences in reliability of the various series. In this case, the standard error of the income variable (0.24) is small, which makes the estimates quite stable: this is then reflected in the resulting t-ratios, which are derived by dividing the estimated coefficients by the standard errors.

* *One-tailed tests are appropriate where an a priori assumption is made regarding the expected sign of the coefficient.*

The coefficient of determination, or R^2, assesses the proportion of the variance of the response which is explained by the independent variables. A high R^2 (for example, over .90) demonstrates that a significant proportion of past variability has been explained, whereas a low R^2 (say of .50) characterizes a lack of fit and generally suggests a need to include further explanatory factors. In this case, the high R^2 of .995 demonstrates that a high "goodness of fit" can be attributed to the estimated joint effects of the independent variables, but it fails to tell us whether an alternative formulation of the equation might not do at least as well.

The <u>F-statistic</u> measures the significance of all explanatory variables in explaining variance in the response by testing the hypothesis that all regression coefficients simultaneously vanish. In most cases our F-statistics are highly significant, which we would expect from the correspondingly high R^2's. Two points should here be noted. First, if any one of the estimated regression coefficients is significantly different from zero according to the results of the t-test (such as the coefficient of PCY or POP), then, providing that the tests are carried out at the same level of significance and against the same alternative, the F-statistic will in almost all cases be significantly different from zero. Our run thus yields the expected result.

However, one of the requirements of the linear regression model is that none of the explanatory variables be highly correlated with any other explanatory variable or with any linear combination of other variables. It is the violation of this assumption that creates the presence of multicollinearity, which indicates that the separate explanatory influence of each of the variables chosen is

weak relative to their joint influence on the dependent variable, and hence the separate influences of the explanatory factors cannot be disentangled. As some degree of correlation is always present, multicollinearity is really a question not of kind but of degree, and there is no firm point at which it ceases to be acceptable and instead becomes "harmful". In general, if at the 5 percent level of significance the value of the F-statistic is significantly different from zero but none of the t-ratios is, then multicollinearity should be regarded as harmful. In the present case, the t-statistics on both of the variables used remain significant, and hence the degree of multicollinearity which is present appears to be small.

Finally, the Durbin-Watson statistic is 1.13, which at the 5 percent level of significance indicates that no autoregression is present. This statistic, which examines the serial correlation of the regression disturbances, therefore implies (for any time series data) that the effect of a disturbance which occurs at one period does not affect subsequent periods, and the favourable outcome of the test allows us to retain our least squares estimates without the fear of a loss of efficiency or a bias of the estimated standard errors.

The inter-city passenger transportation demand model is in some ways one of the least satisfying sector equations that has been developed. Certainly this equation has served to point out the shortcomings and frustrations of the modelling process, for in many cases the additional work that was done (improving the reliability of the series used in the initial May 31 progress report) served only to yield inferior statistical results. Other factors which have been tested include

variables describing price, investment, leisure time, the degree of urbanization, and communications alternatives. It is worthwhile to include a brief note on some of these other possibilities.

In this study price has never proven to be a significant factor in explaining changes in inter-city passenger demand; the sign of the coefficient on price was consistently positive, indicating that as prices increased so too did the demand for the service. This result, although counter-intuitive, does indeed coincide with the observed history of the past 20 years: the important point, so far as the modelling procedure is concerned, is that demand did not increase because the price went up, but rather demand increased in reponse to other (perhaps income or service-related) factors and simultaneously prices also increased. Transportation demand may well have gone up by less than it would have in the absence of an increase in prices, but since price is not functioning as an explanatory factor we cannot include it as a satisfactory variable.

A somewhat similar problem exists with respect to the infrastructure variable, which in some earlier runs exhibited a high t-statistic and the correct (positive) sign. What is impossible to isolate here is the proper direction of causation: if we include INF as an explanatory variable, as we do in some of the following modal share equations, how can we really be sure that it was the rise in the sector's investment in infrastructure that allowed for the increase in demand? Might it not be at least equally true that a prior increase in demand resulted in a need for the construction of additional facilities? The answer, of course, is that we cannot, with the present model, separate the two effects - all we can demonstrate

is that the historical movements of the two series are closely aligned. However, it is generally possible to test the direction of causation by lagging the appropriate variables of the model in question. It was found that the inclusion of a lagged series for infrastructure generally resulted in a smaller t-statistic on this variable, thus suggesting that the change in infrastructure was not in fact responsible for later change in demand. Hence this variable has been omitted in later runs.

Both leisure time and communications alternatives proved to be statistically significant series and of the proper sign (positive for LES, negative for COM). However, in neither case did we feel confident that the series which was utilized* effectively captured the full impact of the phenomenon. A measure of the percentage of the population living in urban areas consistently demonstrated the incorrect sign, and hence has also been omitted from the final formulation of the equation.

With the succeeding paragraphs in mind, several prominent conclusions of the present equation should be stressed. Per-capita income remains a most significant explanatory factor, exhibiting a strong positive influence on transportation demand, while population changes demonstrate a similarly significant relationship. The estimated coefficient gives a measure of the strength of this effect; the model predicts, for example, that at the mean each one dollar increase in

* *For leisure time a measure of the percentage of employees with three weeks or more paid vacation per year, and for communications a series showing the change in the number of non-local phone calls made each year in Ontario.*

per-capita personal disposable income will increase transportation demand by 2.18 million passenger miles. A population increase of one thousand persons will, on the other hand, result in a predicted increase in inter-city transportation demand of some four million passenger miles.

3. Modal Shares

3.1 Historical Modal Shares

Transportation output data from Section 2.1 above have been used to prepare historical modal share relationships for the inter-city passenger sector. Modal shares expressed in percentage terms are presented in Table II-6.

The automobile has been by far the most important inter-city passenger mode for the past 20 years. The share of total inter-city passenger miles accounted for by the auto mode has grown from 87 to 92 percent over the 1955-1974 period. The rail mode ranked second behind the automobile at the outset of the period; however, by 1974 rail passenger miles accounted for only 2.4 percent of the Ontario inter-city total. The relative gains in passenger mile output experienced by the auto and air modes have largely occured at the expense of rail. During the historical period under review, the modal share attributable to the bus mode has remained fairly stable.

It is difficult to explain the causes of occasional aberrations in the modal share distribution. Some are attributable to changes in statistical reporting procedures while others are related to labour disruptions and other factors. For example, the decline in the rail modal share during 1973 was to some extent related to a labour strike by railway workers in the summer of that year; this disruption of service reduced the rail passenger mile total and probably increased the use of other modes.

3.2 Explanatory Variables

The modal share equations disaggregate the inter-city passenger market and seek to isolate the influences of the independent variables on each of the four major modes - auto, air, bus, and rail. Although the final equations are, with the exception of the bus mode, quite successful in explaining changes in relative modal shares (the dependent variable in each case is the annual percent of the total inter-city passenger market captured by each mode), it has proved difficult to specify certain of the parameters of greatest explanatory significance. This is particularly true with respect to service-related factors, which in general express changes in prevailing attitudes or tastes and hence are extremely difficult to quantify.

The equations for each of four modes are shown in Table II-10. Following is a brief description of each of the independent variables which were used, as shown in Table II-9.

(i) Relative price index, which accounts for relative shifts in modal fares, was assembled from published Statistics Canada information (SC 62-002). Two indices were developed, one which weighted price changes by the annual relative importance (in terms of passenger mile contributions) of each mode, and another which ignored passenger mile considerations in favour of a direct cost comparison. With both indices, the actual series used were computed on the basis of the ratio of the price of one

TABLE II-9

INDEPENDENT VARIABLES - MODAL SHARES

Year	Relative Price Indices				Average Family Income	Relative Infrastructure Indices			Relative Time			
	Auto	Rail	Bus	Air		Air	Rail	Road	Auto	Air	Rail	Bus
1955	126	85	111	85	4,490	6	26	68	103	27	143	155
1956	124	84	115	84	4,545	3	55	42	104	26	142	155
1957	132	81	113	82	4,600	4	45	51	105	25	142	156
1958	126	84	113	84	4,690	6	41	53	106	24	141	157
1959	126	82	116	83	4,780	2	36	62	108	23	140	158
1960	121	85	114	85	4,897	10	17	73	110	22	140	159
1961	119	87	111	87	5,014	11	13	76	111	21	139	159
1962	112	83	110	100	5,434	3	17	80	110	22	142	156
1963	110	83	110	101	5,855	4	17	79	109	22	146	152
1964	117	75	112	103	6,275	4	17	79	110	22	147	152
1965	121	73	111	104	6,696	3	23	74	111	21	147	152
1966	118	81	100	99	7,006	7	25	68	111	20	146	153
1967	117	86	104	99	7,316	13	24	63	114	20	145	152
1968	119	75	105	107	7,642	16	21	63	115	19	142	155
1969	110	89	103	100	7,968	14	27	59	117	19	139	157
1970	111	98	103	96	8,294	15	18	67	118	19	136	160
1971	104	92	101	104	8,620	12	20	68	119	18	134	161
1972	95	109	96	98	8,950	11	14	76	121	18	134	160
1973	93	112	96	97	9,453	19	22	58	123	18	133	159
1974	90	122	88	98	9,960	19	23	57	125	18	132	158

one mode to the price of all other modes (i.e. auto ÷ rail + bus + air). The series used here is unweighted.

(ii) Average family income for Ontario has been computed on the basis of Statistics Canada data for Ontario (SC 13-528, 13-538, 13-544). For the early years the information was collected only infrequently and hence some extrapolation was required.

(iii) Relative infrastructure indices were estimated using a number of alternative measures; the final series chosen represents the ratio of the contribution of each mode to the sum of the three individual modal series which were developed for air, rail, and roal (auto & bus) investment. For the air mode, Statistics Canada (SC 51-206) provides national estimates of the annual additions to total operating property and equipment; these were adjusted for Ontario on the basis of the annual ratio of the population of Ontario to the population of Canada. For the rail mode, information is available (SC 52-207) on the annual investment changes in road and equipment property for all companies operating in Canada; these were adjusted for Ontario on the basis of a moving estimate of the ratio of total passenger miles run in Canada. Alternative series based on the annual provincial construction expenditures on relevant property and infrastructure were also attempted, but it was felt preferable to include some measure of operating property and equipment;

this data is at present only collected on a national basis. The series chosen for both the bus and auto modes is the total yearly value of road construction in Ontario (SC 64-201); it therefore does not combine the same measures of equipment and of operating property as do the rail and air series.

(iv) Relative time represents an attempt to develop a parameter which is related to service quality, probably the most critical component of modal choice decisions and yet again the most difficult to successfully quantify. Historical information on changes in selected scheduled trip times of air, bus and rail carriers was collected for 4 representative Ontario city pairs* on the basis of published schedules; changes in the speed of automobile travel were then based on the series developed for bus.**

Clearly, many important factors relating to speed of travel do not appear - travel time, scheduling delays, late arrivals, etc. - nor are modal choices really so distinct: the decision to travel by plane (rather than, say, train) from Ottawa to Montreal, for example, might well depend on the quality of auto or bus service to and from the terminal. Furthermore, reliable time series data was simply

* *These were Toronto-Montreal, Toronto-Windsor, North Bay-Ottawa, Sudbury-Toronto.*

** *The assumption was made that auto travel times were initially 75% of scheduled bus times; by 1974 the relative percentage was assumed to be 85%.*

unavailable for several other important components of service quality, such as frequency of service or dependability. Nor is comparative information on such important factors as trip purpose or average distance travelled per trip available for the required time range. These are clearly areas where the collection of additional data would yield significant benefits.

3.3 Forecasting Model

(a) Introduction

Table II-10 exhibits the equations which have been developed for each mode. Note that those for rail and air are quite satisfactory, whereas the equations for the bus and auto modes, as evidenced by the low R^2 values, fail to satisfactorily explain historical variation in their relative modal share percentages.

(b) Discussion of Results

The quality of these inter-city passenger modal share equations is still not fully satisfactory; although all but the bus equation provide useful forecasting assistance, it remains true that the level of trust that can be placed in the results is lower than we would like to see.

Negative signs are expected on both RPI and TIM, showing that as the price (or time) of one mode decreases relative to the other modes, the level of passenger demand is expected to increase. The sign on AFY should be positive for air (or auto) and probably negative for bus and rail, demonstrating that as average family incomes increase

TABLE II-10

REGRESSION MODEL: MODAL SHARES

General Form of the Basic Modal Shares Model:

IPM = f (RPI, AFY, RIN, TIM)

where

IPM = relative model share of inter-city passenger transportation demand (as a percent of total passenger miles)

RPI = relative price index

AFY = average family income

RIN = relative investment in infrastructure

TIM = changes in time

Basic Equation:

$$\text{AUTO IPM} = b_0 + b_1 (\text{RPI})_t + b_2 (\text{RIN})_t$$

	b_0	b_1	b_2
	941.4	-0.64	0.41
	(38.4)	(-3.82)**	(2.18)**

R^2 = .57

F = 11.4

DW = 1.08

$$\text{RAIL IPM} = b_0 + b_1 (\text{AFY})_t + b_2 (\text{TIM})_t + b_3 (\text{INF})$$

	b_0	b_1	b_2	b_3
	-84.1	-0.005	1.11	0.66
	(-1.14)	(-3.88)**	(2.32)**	(3.63)**

R^2 = .86

F = 32.3

DW = 1.20

Cont'd.

TABLE II-10 Cont'd.

$$\text{AIR IPM} = b_0 + b_1\ (\text{AFY})_t + b_2\ (\text{TIM})_t + b_3\ (\text{RPI})_t$$

36.7	0.004	-1.19	-0.16
(2.11)	(6.31)**	(-2.55)**	(1.79)**

R^2 = .96
F = 118.
DW = .88

$$\text{BUS IPM} = b_0 + b_1\ (\text{RPI})_t + b_2\ (\text{AFY})_t + b_3\ (\text{RIN})_t + b_4\ (\text{TIM})_t$$

70.8	0.16	.0008	-0.08	-0.39
(1.42)*	(.70)	(.89)	(-1.47)*	(-1.85)**

R^2 = .29
F = 1.56
DW = 1.27

---

* *Significant at the .10 level.*
** *Significant at the .05 level.*

there is a resultant shift in demand toward the relatively higher priced (air and auto) modes. RIN should be positive throughout.

The basic trouble with these equations rests with the absence of reliable measures of service quality. What we are essentially attempting to do here is to describe historical shifts in modal shares while being forced to ignore - due to a gross lack of suitable information - many of the major explanatory factors. This difficulty is most apparent in the bus and auto equations, where it has proved impossible to quantify the reasons for changing consumer preferences between the two modes.

A number of further variables have been examined, including a leisure time index, various frequency of service measures, a comfort index, and more realistic travel cost estimates. But in each case the available information was either of a highly unreliable quality or else the basis of its collection was so unsystematic as to render it useless in the present type of time series model.

An alternative procedure for determining modal shares for forecast purposes is to subjectively estimate shares based on historical data (Table II-6).

4. Energy Use Forecasts

4.1 Automobile Mode

(a) Forecasting Methodology

Forecasts of inter-city passenger miles can be produced by the previously described transportation demand and modal share equations. Energy use by the auto mode can then be calculated by the application of the following methodology.

(i) The base year will be 1974.

(ii) The first forecast year is 1975.

(iii) Divide the forecast Inter-City passenger miles in 1975 by load factor to determine <u>Inter-City vehicle miles in 1975</u>.

(iv) Divide the forecast Urban passenger miles in 1975 by load factor to determine <u>Urban vehicle miles in 1975</u>.

(v) Total vehicle-miles in 1975 = (iii) + (iv).

(vi) Urban mileage ratio 1975 $= \frac{\text{Urban VM}}{\text{Total VM}} = U_1$

Inter-city mileage ratio 1975 $= \frac{\text{Inter-city VM}}{\text{Total VM}} = IC_1$

(vii) Calculate 1974 and prior year autos operating in 1975 by multiplying new car sales in each historical year by the survival rates shown in Table II-11; multiply this figure by 10,000 miles per vehicle (or similar number) to determine vehicle miles provided in 1975 by one year and older models.

(viii) New car sales 1975 =

$$\frac{\text{Total VMT's 1975 - VMT's by 1974 and prior year autos}}{\text{10,000 miles/auto}}$$

(ix) Estimate the distribution of 1975 car sales by class, e.g.

sub-compacts	-	19 percent
compacts	-	26 percent
intermediates	-	24 percent
standard	-	31 percent

(see Table II-13 for data on new car registrations by size class for the period 1970 to 1975.)

(x) Fuel Use in Inter-City Travel for 1975:

Step 1:

Read in average fleet fuel efficiencies in inter-city driving for each year from 1961 to 1974:

1960 average IC fuel efficiency = 21.1 mpg
1961 average IC fuel efficiency = 21.5 mpg
1962 average IC fuel efficiency = 22.0 mpg

1974 average IC fuel efficiency = 18.2 mpg

(See Table II-14 for sales weighted inter-city fuel economy figures by model year.)

Step 2:

Read in fuel efficiencies by weight class in inter-city driving for 1975 autos:

1975 sub-compact ave. IC fuel efficiency = 31.0 mpg
1975 compact ave. IC fuel efficiency = 24.9 mpg

1975 intermediate ave. IC fuel efficiency = 18.9 mpg
1975 standard ave. IC fuel efficiency = 16.2 mpg

(see Table II-15 for calculation of 1975 fuel efficiencies by weight class.)

Step 3:

Inter-city gasoline use forecast for 1975:

$$\text{No. 1960 veh.} \times 10{,}000\ \frac{\text{mi}}{\text{veh}} \times IC_1 \div \text{1960 IC mpg} =$$

$$+\ \text{No. 1961 veh.} \times 10{,}000\ \frac{\text{mi}}{\text{veh}} \times IC_1 \div \text{1961 IC mpg} =$$

$$+\ \text{No. 1974 veh.} \times 10{,}000\ \frac{\text{mi}}{\text{veh}} \times IC_1 \div \text{1974 IC mpg} =$$

$$+\ 19\%\ \text{1975 veh.} \times 10{,}000\ \frac{\text{mi}}{\text{veh}} \times IC_1 \div \text{1975 IC mpg (sub compacts)} =$$

$$+\ 26\%\ \text{1975 veh.} \times 10{,}000\ \frac{\text{mi}}{\text{veh}} \times IC_1 \div \text{1975 IC mpg (compact)} =$$

$$+\ 24\%\ \text{1975 veh.} \times 10{,}000\ \frac{\text{mi}}{\text{veh}} \times IC_1 \div \text{1975 IC mpg (inter.)} =$$

$$+\ 31\%\ \text{1975 veh.} \times 10{,}000\ \frac{\text{mi}}{\text{veh}} \times IC_1 \div \text{1975 IC mpg (std.)} =$$

Step 4:

Calculate 1975 fleet average fuel efficiency in Inter-City travel:

$$= \frac{\text{Inter-City VMT's of 1975 autos}}{\text{Fuel consumption of 1975 autos}}$$

(xi) Fuel Use in Urban Travel for 1975:

Repeat Steps 1, 2, 3, and 4 as in (x) above using urban fuel efficiency and urban miles travelled figures to calculate total fuel use in 1975.

(xii) 1976 (and future) Fuel Use Forecast:

The model repeats the procedure in steps (iii) to (xi) above, i.e.,

- calculate Inter-City and Urban vehicle miles for 1976.
- calculate stock of cars in 1976 of 1975 and prior model years. Calculate miles driven by these cars in 1976.
- calculate 1976 autos which must be added to the total stock.
- estimate the distribution of 1976 car sales by class; estimate the urban and inter-city fuel efficiencies of each class.
- calculate energy use by cars of each model year and sum.
- calculate average fleet fuel efficiencies for 1976 autos in urban and inter-city use and read into the program.

This forecasting methodolgy produces as an intermediate calculation a forecast of new car sales and total automobile stock by year. A useful check of the reasonableness of any forecast is to compare these numbers with forecasts of the same statistics from other sources. A further statistic to calculate is the automobiles per capita ratio; this statistic has shown a steady decline in the historical

period and can be expected to continue to decline in the forecast period.*

* *The suggestion is often put forward that a definite saturation level of car registration relative to population exist. There is no consensus as to what is the ultimate saturation level; in fact, there is no consensus on the validity of the application of the saturation concept to automobile registrations.*

TABLE II-11

ONTARIO STOCK OF AUTOMOBILES BY AGE AT DECEMBER 31, 1974

Year	(1) New Car Reg's.	(2) Survival Rate %	(3) Estimated Autos at End of 1974	(4) Adjusted Autos End of 1974 (3) x 1.02
1974	332,219	n = 100	332,219	338,863
1973	374,165	n-1 = 100	374,165	381,648
1972	335,280	n-2 = 100	335,280	341,986
1971	321,835	n-3 = 99	318,617	324,989
1970	260,845	n-4 = 98	255,628	260,741
1969	315,228	n-5 = 96	302,619	308,671
1968	303,310	n-6 = 93	282,078	287,720
1967	268,501	n-7 = 88	236,281	241,006
1966	277,811	n-8 = 76	211,136	215,359
1965	292,442	n-9 = 64	187,163	190,906
1964	251,997	n-10 = 50	125,998	128,518
1963	227,386	n-11 = 37	84,133	85,816
1962	201,339	n-12 = 27	54,361	55,448
1961	185,015	n-13 = 16	29,602	30,194
1960	197,114	n-14 = 10	19,711	20,105
1959	na	n-15 = 5	10,000 est	10,200
1958	na	n-16 = 0	-	-
		Totals	3,158,991	3,222,890

(1) R.L. Polk & Co. (Canada) Ltd. New car registrations as of December 31 each year.

(2) Based on Table II-12.

(3) Col. 1 x Col. 2.

(4) Total of 3,222,890 is equal to 1974 registrations of Ontario automobiles (see Table II-1).

TABLE II-12

U.S. AUTOMOBILE SURVIVAL RATES

CARS IN OPERATION BY MODEL YEAR

	1960 Autos.	Survival	1961 Autos.	Survival	1962 Autos.	Survival
	(000)					
1960	6201*	100				
1961	6201*	100	5513*	100		
1962	6201	100	5513	100	6629*	100
1963	6197	100	5505	100	6614	100
1964	6134	99	5455	99	6629	100
1965	6002	97	5384	98	6626	100
1966	5758	93	5281	96	6573	99
1967	5274	85	5026	91	6401	98
1968	4615	74	4657	84	6183	93
1969	3726	60	4087	74	5804	88
1970	2776	45	3267	59	5058	76
1971	2035	33	2525	46	4724	64
1972	1414	23	1824	33	3343	50
1973	967	16	1268	23	2470	37
1974	682	11	901	16	1813	27

* *Resourcecon estimates*

SOURCE: 1975 Automobile Facts & Figures, p. 28.

TABLE II-13

ONTARIO NEW CAR REGISTRATIONS BY SIZE CLASS, 1970 TO 1975

Year	Standard		Intermediate		Compact		Sub-Compact (1)		Total
	(000)	%	(000)	%	(000)	%	(000)	%	
1970	89	34	41	16	80	31	50	16	260
1971	121	38	57	18	60	19	82	26	320
1972	114	34	66	20	66	20	90	27	336
1973	124	33	61	16	95	25	96	26	375
1974	92	28	75	23	92	28	71	22	330
1975	107	31	82	24	91	26	67	19	347

SOURCE: Canadian New Passenger Car Registrations Reports, R.L. Polk and Co. (Canada) Ltd.

(1) Sub-compacts include minis (i.e. Hondas and Chevettes) in 1974 and 1975.

TABLE II-14

SALES WEIGHTED FUEL ECONOMY OF U.S. AUTOMOBILES
BY MODEL YEAR 1960 to 1974

Year	MPG(1)		Urban MPG(3)	Inter City MPG(3)
	U.S. gal.	Imp. gal.(2)	Imp. gal	Imp. gal.
1960	14.1	16.9	14.5	21.1
1961	14.3	17.2	14.8	21.5
1962	14.7	17.6	15.1	22.0
1963	13.4	16.1	13.8	20.1
1964	14.2	17.0	14.6	21.3
1965	13.7	16.4	14.1	20.5
1966	13.7	16.4	14.1	20.5
1967	13.6	16.3	14.0	20.4
1968	13.2	15.8	13.6	19.7
1969	13.0	15.6	13.4	19.5
1970	13.3	16.0	13.8	20.0
1971	13.0	15.6	13.4	19.5
1972	12.8	15.4	13.2	19.3
1973	12.4	14.9	12.8	18.6
1974	12.2 est.	14.6	12.6	18.2

FOOTNOTES

(1) U.S. EPA, A Report on Automobile Fuel Economy, October 1973, p.33. MPG figures shown on Table 5 increased by 0.75 MPG each year to more closely correspond to U.S. DOT data shown in Figure 8, p.34.

(2) MPG/Imperial gal. = 1.20 MPG/U.S. gal.

(3) Estimate based on 55 percent urban driving and 45 percent inter-city driving. Estimate also based on the assumption that the average highway MPG is 45 percent higher than the average urban MPG, see U.S. EPA, Factors Affecting Automotive Fuel Economy, Sept.1975, p.22. Urban MPG can thus be calculated at 0.86 of average MPG and inter-city MPG at 1.25 of average MPG.

TABLE II-15

FUEL EFFICIENCY BY WEIGHT CLASS 1975 AUTOS

1.) Sales weighted fuel economy of 1975 autos 13.8% higher than in 1974:[a] Therefore ave. urban MPG =

Ave. inter-city MPG (1975) = 18.2 x 1.138 = 20.7 mpg

Ave. urban MPG (1975) = 12.6 x 1.138 = 14.3 mpg

2.) Inter-city fuel efficiency by size class, 1975 autos:[b]

sub-compacts	31.0 mpg
compacts	24.9 mpg
intermediates	18.9 mpg
standards	16.2 mpg

Calculation

$$\frac{0.19\text{ VMT}}{31.0\text{ mpg}} + \frac{0.26\text{ VMT}}{24.9\text{ mpg}} + \frac{0.24\text{ VMT}}{18.9\text{ mpg}} + \frac{0.31\text{ VMT}}{16.2\text{ mpg}} = \frac{\text{VMT}}{\text{ave. mpg}}$$

$$\frac{31\text{ VMT}}{1.49\text{ gal.}} = \text{ave. mpg} = 20.7\text{ mpg}$$

3.) Urban fuel efficiency by size class, 1975 autos:[b]

sub-compacts	=	21.4 mpg
compacts	=	17.2
intermediates	=	13.0
standards	=	11.2

Calculation

$$\frac{0.19\text{ VMT}}{11.4\text{ mpg}} + \frac{0.26\text{ VMT}}{17.2\text{ mpg}} + \frac{0.24\text{ VMT}}{13.0\text{ mpg}} + \frac{0.31\text{ VMT}}{11.2\text{ mpg}} = \frac{\text{VMT}}{\text{ave. mpg}}$$

$$\frac{21.4\text{ VMT}}{1.49\text{ gal.}} = \text{ave. mpg} = 14.3\text{ mpg}$$

FOOTNOTES TO TABLE II-15

(a) *U.S. EPA, Factors Affecting Automotive Fuel Economy, p. 23.*

(b) *Relative proportions of fuel efficiencies between weight classes (but not the efficiencies themselves) based on EPA report cited in "a", Table 30 "Fuel Economy of 1975 Models by Test Weight Class". Ave. vehicle weight in each weight class assumed as:*

sub compact	*2300 lbs.*
compact	*3000 lbs.*
intermediate	*4000 lbs.*
standard	*4700 lbs.*

(b) Sensitivity Analysis

The energy use model developed above will enable the fuel use effects of a range of design or policy variables to be tested. The sensitivity of fuel use to changes in these variables can be determined by comparing the resulting energy use forecasts to the Base Case forecast. The following factors can be tested for sensitivity by the model:

(i) Load Factor:

The present load factor for inter-city automobile travel is estimated at 2.4 passenger miles per vehicle mile. The load factor can be varied to produce varying estimates of future inter-city vehicle miles based on the passenger mile forecast. The energy use impact of these changes in VMT's can then be calculated by the model.

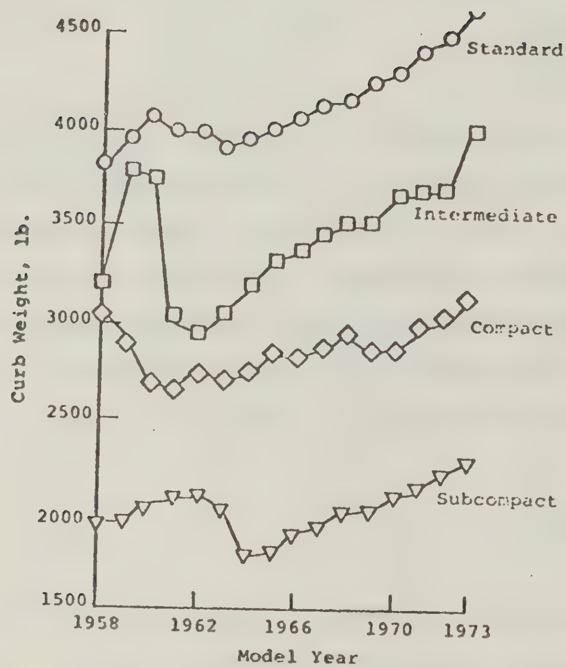
(ii) Weight of Auto:

Automobile weight is one of the major factors influencing energy use per vehicle mile. U.S. vehicles have been generally gaining weight at the rate of 50 to 100 lbs. per year (see Figure II-1). In 1973 the average curb weight of new cars was approximately as follows:

sub-compacts	=	2300 lbs.
compacts	=	3100 lbs.
intermediates	=	3900 lbs.
standards	=	4600 lbs.

FIGURE II-1

CURB WEIGHT BY MARKET CLASS, U.S. SALES 1958-1973



SOURCE: U.S. Environmental Protection Agency, Factors Affecting Fuel Economy, Sept. 1975, p. 10.

One approach to test the impact of different future auto weights than those assumed in the Base Case is to vary the distribution of car sales by weight class and consider the fuel efficiency of each class to remain constant. In other words the energy impact of changing automobile weights in the future would be tested by assuming more of one class of vehicle and less of another.

A second approach is to develop an engineering relationship between weight and energy consumption all other factors remaining constant (such as speed, engine power, drag coefficients, etc.). A problem with this approach is that weight is closely related to engine displacement and horsepower; as a result, a more desirable procedure would probably be to forecast increases in engine displacement and horsepower together with increases in weight. Austin and Hellman (II-3,2678) quantified some of the factors that influence fuel economy through the use of regression analysis using the 1973 certification data for U.S. automobiles. They developed a weight vs. fuel efficiency relationship of:

$$\text{Mpg} = 1.2808 + 52{,}430 \left(\frac{1}{\text{(Inertia Weight)}}\right)$$

It is not clear to us at this stage to what extent such derived relationships are free of the influences

of corresponding shifts in other variables such as engine horsepower, compression ratios, etc. Consideration should continue to be given the possibility of developing explicit weight vs. fuel efficiency ratios (see also Ref. II-4).

(iii) Drag Coefficients:

Aerodynamic drag is a significant factor affecting fuel consumption in inter-city passenger travel where speeds are high. In general the horsepower necessary to drive a car at constant speed is the sum of the mechanical and aerodynamic resistence. As Figure II-2 shows power requirements expended to overcome aerodynamic drag increases sharply with speed; at speeds in excess of 60 mph drag becomes the most important factor affecting automobile power requirements. No simple correlation exists between fuel economy and drag as the drag force is dependent on the square of vehicle speed and the drag coefficient product. The drag coefficient is a constant for a given automobile and is expressed as:

$$\text{Drag Coeff.} = \frac{(14.87)\ \text{Drag Force}}{\text{Frontal Area} \times V^2 \times \frac{\text{Air Density}}{2}}$$

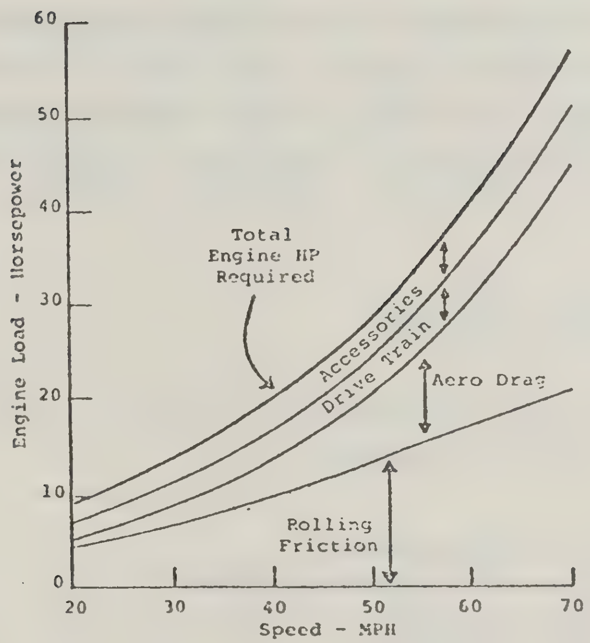
where	Drag coefficient	- dimensionless
	Drag force	- in lbs.-force
	Frontal area	- in sq. ft.
	Veh. Velocity	- in mph
	Air Density	- in lbs. per cu. ft.

Hurter et al (II-4, 152 to 162) have calculated that for a 20% reduction in drag coefficient (from a value of about 0.45) fuel use efficiency would be increased 0.70% in the Federal Driving Cycle (assuming a combination of

FIGURE II-2

EFFECT OF SPEED ON POWER REQUIREMENTS

(STANDARD SIZE CAR)



SOURCE: U.S. Environmental Protection Agency, Factors Affecting Fuel Economy, Sept. 1975, p. 4.

urban and inter-city driving), 2.5% at 5 mph, and 3.8% at 70 mph. The belief is that a 20% improvement in drag coefficients from present automobile values can be achieved by incorporating simple styling changes in automobile design.

Relationships should be established between fuel use efficiency increases associated with reductions in drag coefficients of, say, 10%, 20%, 30%, 40% and 50% for a car driving at 50 mph (typical of inter-city travel). The resulting improved fuel use efficiency numbers can then be introduced into the energy use model at the desired timing to calculate the impact of improved styling on total fuel use.

(iv) <u>Convenience Devices:</u>

The following convenience devices can have a negative effect on fuel economy:

air conditioning
automatic transmissions
power steering
power brakes
power seats, windows

Accessories can add to vehicle power requirements in two ways: by consuming power themselves and by adding weight. The two most energy consumptive devices are air conditioners and automatic transmissions.

The fuel economy figures by model year as shown in Table II-16 relate to the U.S. auto fleet and reflect the proportions of convenience equipment which this stock contains. In using these figures for Ontario the implicit assumption is that the Ontario vehicles are similarly equipped to U.S. cars. In 1975 the proportion of U.S. cars by size class equipped with the major convenience items was as follows (II-6, 6).

PERCENTAGE OF 1975 AUTOS EQUIPPED

	sub-compacts	compacts	intermediates	standards
auto. trans.	50	75	98	98
air conditioning	5	20	65	85
power steering	5	35	90	95

An effort should be made to estimate the proportion of Ontario vehicles equipped with air conditioners, etc.; also fuel efficiency changes associated with these devices should be developed. Changes in the installation and use of such equipment can then be assumed and the impact on fuel use calculated by the energy model.

(v) Rolling Resistence Reduction:

Rolling resistance reduction can be made independently of weight reductions by altering tire characteristics.

Steel belted radial tires shows improvements in fuel efficiency of 2.5% to 4% (II-5, 53) depending on the test source and automobile operating conditions which are assumed. An analysis of the change in radial tire usage would be required. Based on this analysis the improved fuel use efficiency numbers can be introduced into the energy use model with the corresponding timing of introduction and the impact on total fuel use calculated.

(vi) Modal Shifts:

The impacts of modal shifts on energy consumption in the inter-city automobile sector can be calculated by first estimating the change in auto vehicle miles from the base case forecast as a result of the shifts. The energy use model will then calculate new energy use totals based on the change transportation output numbers.

In similar fashion to the above the effect on fuel use of greater or lesser amounts of travel per vehicle per year can be calculated.

(vii) Engine Technology:

Alternatives to the conventional gasoline engine may be produced in large numbers in the future and the use of alternative engines could have a significant impact on fuel economy. The table

below shows estimates of comparative fuel economies of alternative engines to the conventional gasoline internal combustion type which are expected to be in use in the near future:

Fuel Economy of Vehicles Equipped With Alternative Engines*
(% change compared to 1973 vehicle of same weight)

Worse Fuel Economy	Equiv. Fuel Economy	Better Fuel Economy
1. Rotary: 35% loss	2. Pre-chamber stratified charge (Honda CVCC)	1. Diesel: 40% to 70% gain. 2. Conventional engine with catalyst: 0% to 15% gain. 3. Open chamber stratified charge (PROCO): 12% gain.

* *Ref. II-6, 21.*

Fuel efficiency ratios should be developed for a range of engine types. The desired proportion of alternative engines with their corresponding fuel efficiency ratios could be introduced into the energy use model to assess the impact of these technologies on fuel use.

(viii) Direct Input of Fuel Use Efficiencies

The impact on fuel use in Ontario of assuming fleet average performances of, e.g. the proposed Federal standards of 24 mpg in 1980 and 33 mpg in 1985 can be calculated by directly

inputing these numbers into the model in the years desired. The fleet average performance standards for new car sales reflect both the distribution by weight class of the vehicles sold and the mileage achieved by each vehicle weight class; consequently, for each fleet average performance standard the combinations of these two factors which produce the fleet average performance standard can be explored as well as the effect of the standards themselves.

(ix) Other Factors:

Any other factors which it is desired to test can be evaluated by the same procedure as described in the discussions above: the requirement is that the effect of the factor to be tested is first calculated in terms of the effect it would have on transportation output or fuel use efficiency. These calculated changes in transportation output or fuel efficiency or both are then introduced into the energy demand model and a forecast produced.

4.2 Air Mode

(a) Forecasting Methodology

It is not possible to identify separately the fuel use in Ontario associated with inter-city air travel within the province. As a result fuel efficiency ratios for short haul traffic will be postulated based on published data of energy use per seat mile or passenger mile for the type of air fleet in service in Ontario, and based on the load factor applicable to Ontario inter-city service.

Forecasts of passenger miles of travel by the air mode will be produced by the transportation demand and modal share equations. Energy use can then be forecast by multiplying these estimates by energy intensiveness factors which are developed depending on load factor and assumptions regarding the state of technology and airline operating procedure.

(b) Observed Energy Intensiveness

Most passenger miles of service in Ontario are produced by Group I carriers. A majority of the passenger mile demand is served by Air Canada with jet aircraft, principally stretch DC-9's and 727's. C.P. Air's routing is confined to the Toronto-Ottawa-Montreal corridor with service provided by 727 and 737 jets. A small amount of jet service is provided by Group II regional carriers such as Transair and Nordair. Group III (Great Lakes, Norontair) and smaller carriers serving Ontario centres on typically shorter hops use propellor driven aircraft.

It is presently estimated that aircraft providing inter-city passenger service in Ontario operate at about a 60 percent load factor based on the information of Table II-16. It is assumed that most of the routes operate in the 50 percent load factor range typical of the regional carriers but the large amount of travel on the Toronto-Ottawa-Montreal route would increase this percentage considerably.*

The fuel efficiencies of various aircraft types operated by Canadian Group I and Group II carriers for various stage lengths is shown in Figure II-3. Assuming 300 mile stage lengths as typical of Ontario inter-city service the average fuel use of stretch DC-9 and Boeing 727 aircraft is in the order of 37 seat miles per gallon of aviation turbo fuel. Based on the estimated average load factor of 60 percent this is equivalent to 22.2 passenger miles per gallon or 6,969 Btu's per passenger mile. Taking into account the smaller and presumably less efficient, lower load factor aircraft on non Class I and II carriers, an average energy intensiveness factor of 7,000 Btu's per passenger mile is considered appropriate.** On this basis, total 1974 inter-city air passenger output of 1,534 million passenger miles would have required 10,738 $\times 10^9$ Btu's of energy. Virtually all energy would have been derived from aviation turbo fuel.

* *Based on passenger mile information derived by Resourcecon from passenger origin-destination statistics, 38 percent of total Ontario passenger miles in 1974 were travelled on the Toronto-Ottawa-Montreal route.*

** *Maddalon in his paper, "Rating Aircraft on Energy", Astronautics and Aeronautics, Dec. 1974, calculates a fuel efficiency figure for the Boeing 727-200 on flight averages of 498 miles at a 53 percent load factor of 7,392 Btu's per passenger mile.*

TABLE II-16

PASSENGER SERVICE LOAD FACTOR
CANADIAN AIR CARRIERS, 1974

Type of Carrier	Available Seat Miles	Revenue Pass. Miles	Load Factor %
	CLASS 1 & 8 LICENCES[1]		
	(000,000)		
Air Canada & C.P. Air	22,496	14,131	63.0
Regional Carriers[2]	1,570	798	50.8
	CLASS 8 LICENCE ONLY		
	(000,000)		
AC, CP, and Regional	10,986	6,928	63.1
	ESTIMATES FOR FISCAL 1976		
Norontair[3]	222,000	30,000	36.0

SOURCE: SC 51-001, Transcontinental and Regional Air Carrier Operations.

(1) Class 1 licence is for commercial air service operated wholly within Canada. Class 8 licence is for internationally scheduled commercial air services.

(2) Regional carriers include Eastern Provincial, Nordair, Pacific Western, Quebecair, and Transair.

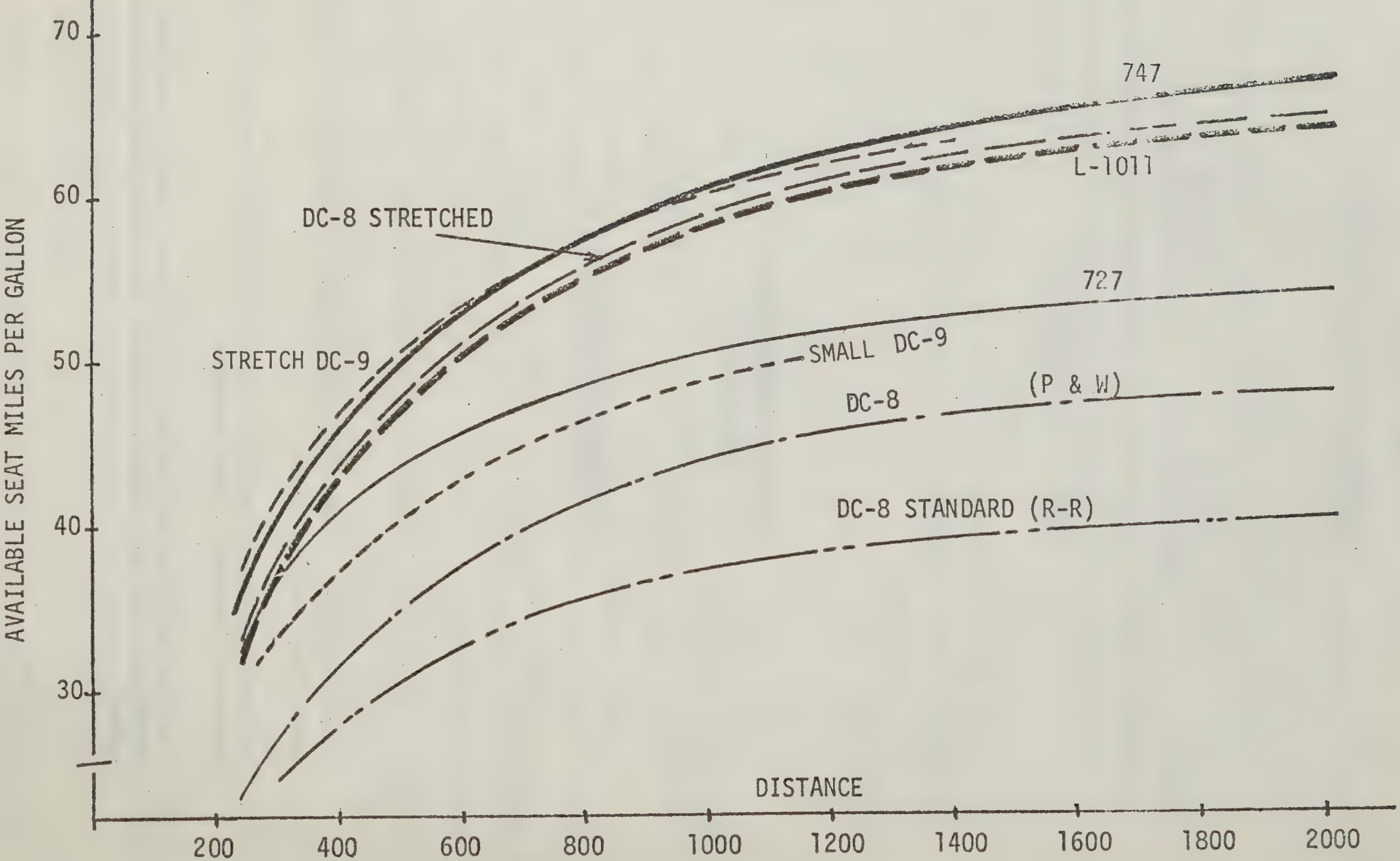
(3) Information supplied by Mr. W.D. Miller, Ontario Ministry of Transportation and Communications, in correspondence of July 30, 1976.

FIGURE II-3

AVAILABLE SEAT MILES PER GALLON VS DISTANCE

AIR CANADA'S FLEET IN CURRENT MIXED

CLASS CONFIGURATIONS



SOURCE: Glenn, C.H., "Possible Impact of Petroleum Shortages on Canadian Air Transportation", Paper prepared for presentation to the Institute of Combustion and Fuel Technology of Canada, Toronto, April 22/76. Mr. Glenn is vice-president fleet planning for Air Canada.

(c) Sensitivity Analysis

The sensitivity of energy use in the inter-city air mode to changes in load factors, technology, or operating techniques would be evaluated by calculating the effect of each of these changes on energy efficiency and multiplying transportation output by the revised energy efficiency values. The timing of the changes could be varied as desired.

Maddalon (II-7,43) has calculated a series of potential reductions in energy use by the air mode which would result from a range of actions as outlined follows:

Change Technology, etc.	Percentage Reduction in Fuel Use
Present aircraft	
Improved operations	
Cruise-speed reduction	2
Optimum flight profile	5
Improved ground manoeuvres	0.5
Reduced fuel reserves	0.5
Flight training simulation	0.5
Cumulative	5
High-density seating	7-35
Load factor = 75%	30
Advanced technology	
Supercritical aerodynamics	11-15
Composite structures	11
Propulsion (FAR 36-10 approx)	6-8
Active controls	4
Cumulative	22-30 +
Terminal compatible aircraft	5-18
Acoustic composite nacelle	3
Far-term aircraft	
Very large aircraft	30-40
Skin-friction drag reduction	20+
Hydrogen fuel	5-15

As can be seen the greatest potential for increasing fuel economy in present fleets is through increases in load factor. The impact of load factor changes and various technological innovations on energy consumption are discussed below:

(i) Load Factor:

Jet aircraft fuel consumption is relatively insensitive to increasing passenger load; the Boeing 727-100's fuel consumption increases only about 0.3% per additional 1,000 lbs. at normal loaded weights (II-8, 2-26). Thus the additional fuel required for higher payloads is quite small and improved fuel efficiency is almost directly proportional to increased load factor. For purpose of this analysis it will be assumed energy intensity factor will change by 85 percent of the reciprocal of the proportionate change in load factor. That is, if load factor in Ontario inter-city air travel was increased to 70 percent (from 60 percent) fuel use would decrease from the presently estimated 6,969 Btu's per passenger mile to about 6,100 Btu's per passenger mile.*

A 60 percent load factor for inter-city air traffic in Ontario would appear to be quite good. If this 60 percent estimate is correct there is not a large scope for fuel use improvement in Ontario on this score. A 70 percent load factor on routing within Ontario would be close to the upper limit.

(ii) Seating Densities:

Increasing seating densities on aircraft will decrease fuel use per passenger so long as load factors remain constant. A 10 percent increase in seating density would result in a reduction in fuel use per passenger to $\frac{1}{1.10}$

* *70 percent load factor is a 17 percent increase over 60 percent.*
Fuel use efficiency = $\frac{6{,}969}{1 + (.17 \times 0.85)}$ *= 6,089 Btu/pass. mi.*

of the original consumption figure, assuming no additional fuel use for the additional passengers carried. As for the situation with load factor it will be assumed fuel use efficiency will change by 85 percent of the proportionate change in seating density because of the extra fuel use associated with the extra load.

Air Canada has estimated that if its aircraft were modified to all economy seating configurations by 1980, together with the retirement of the standard DC 8's by that time, the average available seat mile per gallon for the fleet would improve by nearly 15 percent (II-9, 5). Figure II-4 shows the fuel efficiency characteristics of Air Canada's various aircraft types if they were all modified to all-economy configuration.

Air Canada recently announced its intention to increase seating densities on its Beoing 747's, Lockheed 1011's, and DC 9's as follows (II-10, 1).

Seating Densities

	Present	Planned	Increase %
DC 9's	95	102	7.4
747's	365	431	18.0
L1011's	257	284	10.5

The DC 9's would be an all-economy configuration but the 747's and L1011's would retain reduced size first class sections. The removal of the first class section on the airline's 52 DC 9 aircraft will eliminate first class service by Air Canada on almost all short haul domestic flights. The 747's will be converted by early 1979 and the L1011's by early 1978.

Clearly the greatest scope for short term energy fuel efficiency increases will come from a combination of increased load factors and seating densities. A 10 percent increase in load factor combined with a 10 percent increase in seating density would increase fuel use efficiency by about 16 percent.

Wide bodied or derivative* aircraft allowing higher seating densities per unit of aircraft weight can offer large potential fuel economies per passenger mile. Grey (II-11) has calculated that an increase of 30 percent in the passenger load of an aircraft type now in service can yield a 20 percent improvement in passenger miles per gallon. More dramatically a stetch version of a B-747 with double deck seating, increasing seats from 440 to 725, would increase energy efficiency in the order of 50 percent. Ontario routes and demand projections must be studied further to determine the extent to which higher density seating aircraft could be effectively utilized.

* *Aircraft derived from existing designs such as the "stretch" versions of the DC-8.*

(iii) <u>Reduced Cruise Speed:</u>

It was calculated in 1974 by Pilati (II-12) that if the U.S. domestic passenger fleet reduced cruise speeds by 0.02 Mach*, its fuel requirement would be reduced by 1.3 percent. It was further calculated that system wide reduction to long range cruise speed (the minimum fuel consumption cruise speed) would reduce fuel requirements by about 3 percent. These reductions are quite small due to the brief cruise time for short flights and the fact that half of all airline hops in the U.S. are under 260 miles.

It can be expected that Ontario inter-city air fuel consumption could be reduced in this same range, i.e. 2 percent, through reduced cruise speeds. Though fuel use will decrease with decreased speeds, it will be recognized that crew and maintenance costs will increase.

(iv) <u>Optimum Flight Profile:</u>

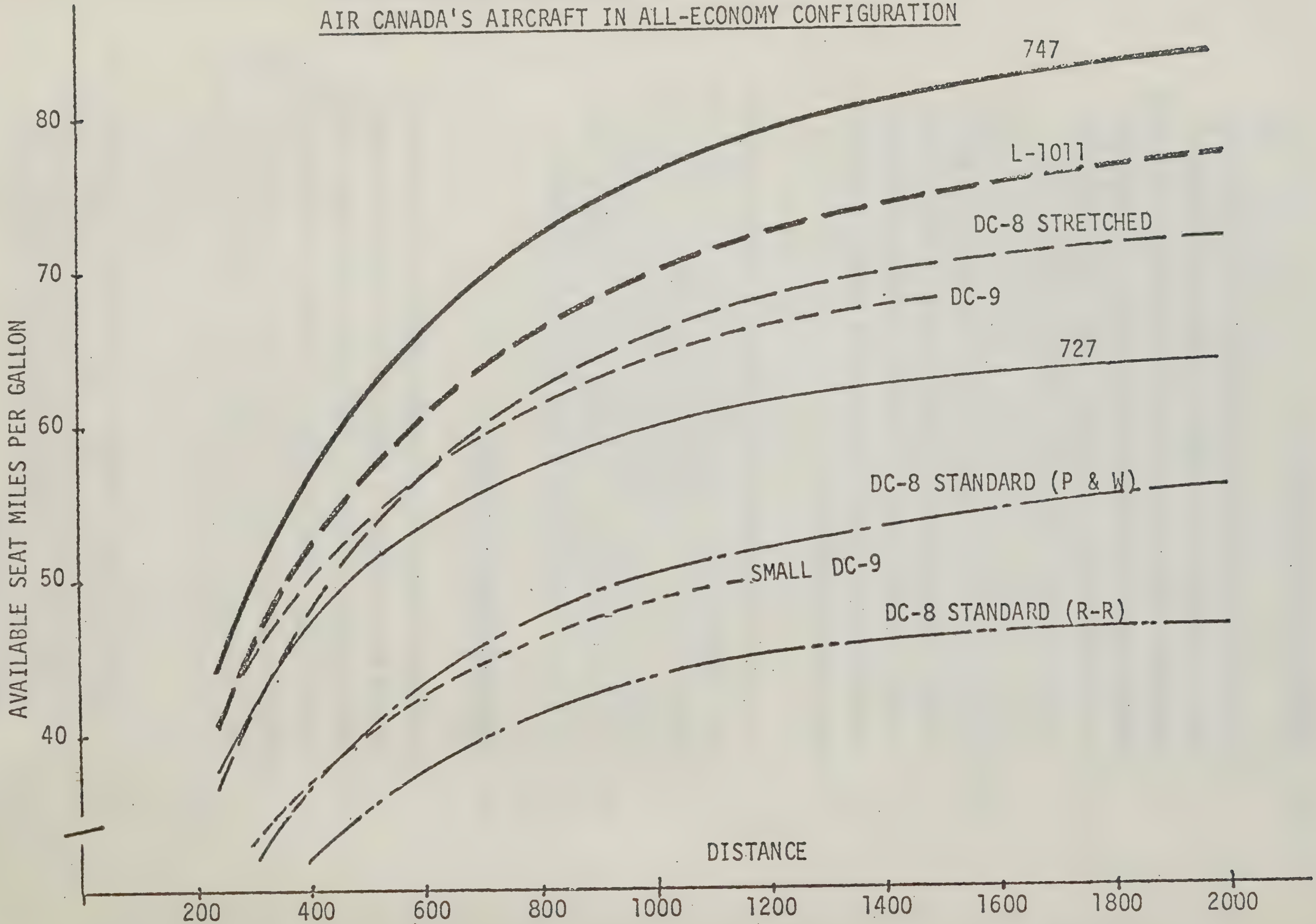
Maddalon (II-7, 41) estimates U.S. airlines could save about 5 percent of fuel by flying fuel-optimum flight profiles. The basic idea is to spend more flight time at cruise attitude where fuel economy is greatest. Almost half the saving comes from climbing at slower speeds and

* *Aircraft flight characteristics vary with altitude as does the speed of sound. Hence an aircraft's speed is stated as a ratio of its airspeed to the speed of sound at the altitude at which it is flying. At 30,000 feet the speed of sound is 678 mph and 0.02 Mach is 13.5 mph.*

FIGURE II-4

AVAILABLE SEAT MILES PER GALLON VS FLIGHT DISTANCE

AIR CANADA'S AIRCRAFT IN ALL-ECONOMY CONFIGURATION



SOURCE: Glenn, C.H., "Possible Impact of Petroleum Shortages on Canadian Air Transportation", Paper prepared for presentation to the Institute of Combustion and Fuel Technology of Canada, Toronto, April 22/76. Mr. Glenn is vice-president fleet planning for Air Canada.

steeper angles in order to quickly reach cruise altitudes. Optimum selection of speeds and altitudes for particular flight segments account for the rest. The scope of fuel use efficiency increases from the application of flight profile modifications to Ontario routes is presently unknown.

(v) Alternative Ground Procedures:

In 1971 an estimated 4.2 percent of the U.S. domestic passenger fleet fuel was consumed in taxiing and idling on the ground (II-8, 2-30). Reducing the number of engines used on the ground and towing aircraft have been suggested to reduce fuel consumption.

(vi) Advanced Technology*- Supercritical Aerodynamics:

As an aircraft approaches sonic speed shock waves form which increases drag. Supercritical aerodynamics can increase the speed at which this drag rise occurs or by improving structural efficiency through wings of reduced sweep which fly at current speeds. Energy savings through such designs may be 11 to 15 percent greater than current aircraft.

(vii) Advanced Technology - Composites:

The high strength-to-weight ratios of composite materials such as graphite epoxy will significantly reduce structural weight and thereby fuel consumption. Compared to an aluminum airplane

* *The following discussion of fuel efficiency improvements through technology advances is taken from Ref. II-7, 37 to 39.*

an aircraft employing about 40 percent composite structure would reduce fuel needed about 11 percent.

(viii) <u>Advanced Technology - Improved Propulsion:</u>

Advances in engine performance can be attained through higher overall pressure ratios, bypass ratios of 6 or more, improved turbine-cooling, aerodynamic design improvements in the compressor, turbine, and fan, and composites which permit lower weights, and permit higher turbine inlet temperatures, and more efficient fans.

A 1985-technology engine would meet the same noise standards as a present day converted engine using 8 percent less energy.

(ix) <u>Advanced Technology - Active Control Systems:</u>

Active controls will make possible aircraft designed for both lower structural loads and reduced drag. As a result, they will save fuel. Active controls can limit manoeuvre and gust loads, suppress flutter, and compensate for decreased static stability through fly-by-wire techniques. Reduced static stability permits decreased tail size, weight, and drag. Active control system benefits are very sensitive to configuration; average fuel savings may be about 4 percent but will vary considerably from aircraft to aircraft.

(x) Advanced Technologies - Combined:

Combining all of the preceding advanced technologies could reduce fuel consumption from 22 to 30 percent depending on noise standards to be met. Assumptions remain to be made concerning the likely timing and extent of such energy conserving technologies into Ontario service. The introduction of the technologies awaits the development of a new generation of aircraft. A new generation of aircraft is not to be in service before the 1985 - 1990 period; the impact would not be felt until even later when these aircraft represented a substantial proportion of the aircraft fleet.

4.3 Bus Mode

(a) Forecasting Methodology

Energy use associated with inter-city passenger bus travel within Ontario is not reported for all firms comprising this sector. Consequently, it has been necessary to develop fuel use relationships based on the activities of those firms for which published statistics are available (II-13). A fuel efficiency ratio has been developed based on an estimated load factor for inter-city bus travel in the province.

(b) Observed Energy Intensiveness

As part of the analysis in Section 2.1 (c), a load factor measure was derived for the inter-city bus mode. On the basis of a typial bus having a capacity of 45 seats and an average load of 20.5 passengers, a load factor of approximately 46 percent was calculated. This load factor is a rough approximation and further efforts should be made to improve upon its quality.

An estimate of fuel use efficiency was derived using published statistics for the largest inter-city bus operators within Ontario. For 1972, the most recent year for which published statistics are available, those firms sampled reported fuel use totalling 950.9 x 10^9 Btu's and transportation output totalling 39,548,000 revenue vehicle miles.* If the transportation output measure is expressed

* *Fuel use totals include 887.8 x 10^9 Btu's of diesel fuel and 63.1 x 10^9 of gasoline. Fuel use and revenue vehicle mile statistics reported in SC 53-002.*

in passenger mile terms, the fuel use efficiency at a 46 percent load factor is as follows:

$$\frac{\text{energy use}}{\text{transportation output}} = \frac{950.9 \times 10^9 \text{ Btu's}}{811 \times 10^6 \text{ pass.mi.*}} = \text{1,173 Btu's/pass. mi.}$$

For the base year of this forecast (1974), it is estimated that inter-city bus travel accounts for 863 million passenger miles,** and fuel efficiency is 1,173 Btu's per passenger mile at 46 percent load factor. On an energy content basis, 93.4 percent of energy requirements were derived from diesel oil and 6.6 percent from gasoline.

* *39.584 x 10^6 veh. miles x 20.5 passengers - 811 x 10^6 pass. mi.*

** *Table II-4.*

(c) Sensitivity Analysis

The energy use impacts of a series of design and policy options can be evaluated using the base case forecast as a standard of comparison. The factors to be considered in the sensitivity analysis are discussed below:

(i) Load Factor:

The current load factor for inter-city bus travel is 46 percent (20.5 passengers per vehicle mile for a typical bus having a seating capacity of 45).

The model allows for the introduction of changes in load factor in order to test the sensitivity these changes could have upon energy intensity factor (Btu's/pass. mi.) for this mode. Assume that the energy intensity factor reduces by 85 percent of the reciprocal of the increase in load factor; for example a 10 percent increase in load factor would decrease the energy use per passenger mile by a factor of $\frac{1}{1 + (.10 \times 0.85)}$. Fuel efficiency changes can be calculated on this basis for any percentage increase or decrease in load factor that may be postulated.

(ii) Vehicle Size:

Generally speaking, the size and weight of buses used for inter-city service have been increasing over time; this is apparent from the following table, which indicates the percentage share of

Ontario inter-city buses by seating capacity for the years 1970 and 1974.

Bus Seating Capacity	1970 %	1974 %
Less than 39 seats	26.2	18.9
More than 40 seats	73.8	81.1

SOURCE: Statistics Canada 53-215 and 53-002.

As buses increase in size seating density appears to increase at a greater rate than weight so that fuel efficiency increases with size, load factor remaining equal. For the two bus size ranges indicated above, fuel use efficiency measured in Btu's per vehicle mile and Btu's per passenger mile have been estimated as follows:

Bus Seating Capacity	Energy efficiency		
	Miles/ gallon*	Btu's/ vehicle mi.	Btu's/ pass.mi.**
Less than 39 seats	7	24,000	1,490
Greater than 39 seats	6	28,000	1,366

* *N.D. Lea and Associates Ltd., Intercity Highway Passenger Transportation Sector Technology and Productivity, 1975, p.93.*

** *At 46 load factor assuming a 35 seat and a 45 seat bus. The reader will note that these fuel efficiency values are somewhat larger than the value calculated for the base year (i.e. 1,173 Btu's/pass. mi.). The difference is attributable to a discrepancy between the miles per gallon estimate taken from the N.D. Lea study and actual fuel economy (6.9 miles/gallon) experienced by the bus operators reporting to Statistics Canada.*

The model will enable us to test the implications from an energy use standpoint of variations in the composition of the inter-city bus fleet. For example, assumptions regarding the replacement of smaller capacity vehicles by larger capacity units can be tested. All that is required is that the fuel efficiency ratios for various size classes be known. By distributing projected passenger mile output between various size classes, the energy use effects can be evaluated.

The use of larger buses (in excess of 40 feet) on inter-city routes will necessitate changes in regulations governing allowable length.

(iii) Drag Coefficients:

The methodology proposed in section 4.1 c (iii) for evaluating the energy use impacts associated with reductions in drag coefficients can be adopted for use in this section.

(iv) Technological Improvements:

Modest improvements in bus engine and drive-train components can be expected to increase fuel economy in the short term. In the case of buses which are already dieselized (which is largely the case for Ontario's inter-city fleet) the fuel economy gain of 1980 vehicles is likely to be limited to 15 percent over 1974 levels (II-5, 94).

The comments in Chapter III, section 4.3 b dealing with inter-city truck technology are applicable here also.

(v) Speed:

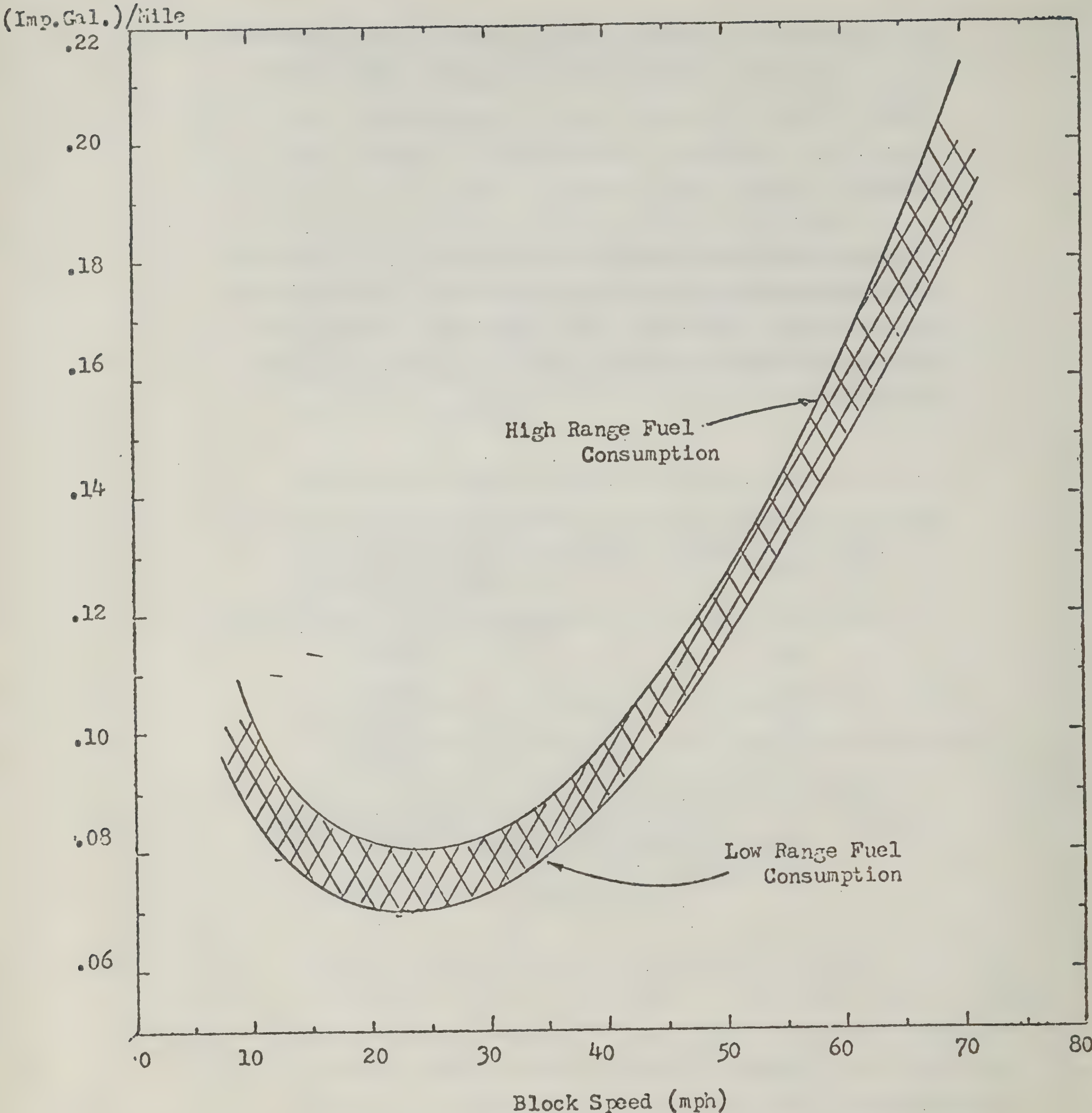
Fuel use by the inter-city bus mode is a function of block speed*; the relationship is indicated in Figure II-5. The N.D. Lea study has quantified the relationship between vehicle speed and fuel consumption:

Speed	Energy Consumption (Btu's/vehicle mile)
40	22,940
50	36,500
60	39,940
70	51,240

SOURCE: N.D. Lea and Associates Ltd., Intercity Highway Passenger Transportation Sector Technology and Productivity, 1975, p. 99.

* *Block speed is the average speed between two points.*

Figure II-5



BUS FUEL CONSUMPTION VERSUS SPEED

SOURCE: M. Rubenstein and E. Miller - title unknown. Unpublished material made available by Dr. R. Wolfe, University of Toronto/York University Joint Transportation Program.

According to the Rubenstein and Miller study*, the average block speed of inter-city buses operating in the Windsor - Quebec City corridor is on the order of 53 miles per hour (20,000 - 23,000 Btu's per vehicle mile). By holding all other variables constant and introducing into the energy use model fuel use efficiencies with various block speeds, the energy use effects of potential speed regulations could be evaluated.

(vi) Other Factors:

Any number of other factors thought to have energy use implications can be evaluated using the same basic procedure outlined for the factors described above. Included in this list are factors such as: the introduction of convenience or comfort equipment (air conditioning, food and beverage dispensing equipment, etc.); reductions in rolling resistance facilitated by tire design changes; etc. The procedure to be used is as follows: the effect of the factor is quantified in transportation output or fuel use efficiency terms; the effects are then introduced into the energy use model and the impact on total fuel use calculated.

* *Title unknown. Unpublished material made available by Dr. R. Wolfe, U of T/York University Joint Transportation Program.*

4.4 Rail Mode

(a) Forecasting Methodology

Projections of inter-city railway transportation demand may be derived using the transportation output and model share equations. Energy requirements may then be forecast as the product of demand and an energy intensiveness factor.

(b) Observed Energy Intensiveness

One of the problems characteristic to the other modes studied is the lack of historical energy consumption data in form suitable for forecasting purposes. This problem is also common to the inter-city rail passenger sector. A discussion of the availability of rail energy use statistics is included in Chapter III, Section A, 4.1.(a).While energy use statistics are published on a provincial basis for the railways, a disaggregation by end use (package freight, bulk freight or passenger) is not provided. It is therefore necessary to split rail energy consumption between freight and passenger use. The discussion in Chapter III, Section A, 4.1.(a) describes the methodology employed to arrive at estimates of energy use for freight and passenger operations.

It is necessary to derive a load factor estimate for Ontario inter-city rail passenger, in order to calculate an energy intensiveness factor for inter-city passenger service. Load factor estimates for rail passenger services provided by C.P. and C.N. were prepared as part of the Ministry of Transport study (II-14) cited earlier. Taking into consideration only those routes completely within

Ontario plus the Ottawa-Montreal, Toronto-Montreal and that part of the transcontinental service within Ontario, it is possible to derive an aggregate and appropriately weighted load factor of 43 percent for 1974 (Table II-17). For purposes of simplification, it is assumed that this load factor applies to rail passenger services provided by other smaller railways operating within Ontario.

Ontario inter-city rail passenger energy consumption and transportation output is estimated at 3,787 x 10^9 Btu's* and 894 x 10^6 passenger miles (Table II-6), respectively for 1974. The energy efficiency value for the inter-ctiy passenger sector is thus 4,236 Btu's/ passenger mile at 43 percent load factor.

(c) Sensitivity Analysis

The sensitivity analysis can evaluate the extent to which load factor changes, new technologies or alternate operating techniques may effect energy use by the inter-city rail mode. The effect of each of these factors upon energy can be determined and alternative energy use forecasts prepared based on projected transportation output and alternative energy efficiency values. Factors which can be considered in a sensitivity analysis are discussed below:

* *Chapter III, Section 4.1.a. provides an historical series for rail mode passenger service energy consumption. From the 1974 total, 286 x 10^9 Btu is deducted to allow for GO transit rail service.*

TABLE II-17

ONTARIO RAIL PASSENGER LOAD FACTORS, 1974

Service	Pass.Mi. (000)	L.F. %	Relative Wt.	Weighted L.F.
1. CP SERVICES				
Toronto-Havelock	4,235	30.9	.036	1.11
Toronto-Hamilton	829	29.0	.007	.20
Sudbury-Sault	1,120	14.0	.009	.13
Sudbury-White River	996	10.0	.008	.08
Montreal-Ottawa	2,655	29.5	.022	.65
Transcontinental	109,098	53.9	.918	49.48
Total	118,933			51.65
2. CN SERVICES				
Toronto-Kingston	7,637	39.9	.012	.47
Toronto-Ottawa	4,634	32.3	.007	.28
Toronto-Stratford	3,570	23.8	.006	.13
Toronto-North Bay	16,564	32.9	.026	.84
Toronto-Niagara Falls	9,561	21.2	.015	.31
Toronto-Stouffville	1,866	25.1	.003	.07
Ottawa-Brockville	24,815	39.1	.038	.50
Toronto-London	43,765	25.6	.068	.73
Toronto-Windsor	108,912	32.6	.168	5.49
Toronto-Guelph	1,731	26.5*	.003	.07
Hearst-Nakina	41	2.7	-	-
Hornepayne-Man.	1	.1	-	-
T.B. - Souix Lookout	140	5.6	-	-
Winnipeg-T.B.	1,092	13.7	.002	.02
Montreal-Toronto	244,062	52.0	.378	19.63
Montreal-Ottawa	14,752	37.1	.023	.85
Transcontinental	163,296	47.0	.253	11.87
Total	646,439			41.21

** 1972 load factor.*

Cont'd.

TABLE II-17 Cont'd.

Service	Pass.Mi. (000)	L.F. %	Relative Wt.	Weighted L.F.
3. AGGREGATE LOAD FACTOR CP AND CN				
CP	118,933	51.65	.155	8.01
CN	646,439	41.21	.845	34.82
Total	765,372			42.83

SOURCE: MOT, A Report on Canadian Passenger Rail Services, 1975.

(i) Load Factor:

Improved load factors offer the best potential for substantial energy savings by the rail passenger mode. As has been assumed for the air and bus modes a given percentage increase in load factor will be estimated to improve fuel use efficiency by 85 percent of the reciprocal of that percentage change - e.g., a 10 percent increase in load factor will change fuel efficiency by $\frac{1}{1 + (.10 \times 0.85)}$.

(ii) Technological Developments:

Technological developments could have important energy use implications for the rail mode. Technological improvements are likely with respect to motive power sources, suspension systems, computerized control facilities and further development and usage of light weight materials for rail car and engine construction.

(iii) Rail Electrification:

The most likely future technological change in rail passenger travel will be rail electrification. From a number of operating points of view electric rail motive power is superior to the conventional diesel-electric source. Capital and maintenance costs of electric units are less; the power to weight ratio is 3 to 5 times greater (II-15, I-3), thus there is extra power available for improved speeds, acceleration and negotiation

of grades; and the overall weight of the unit is less as the need for generators, fuel carrying equipment, etc. is eliminated. However, the major drawback of rail electrification is the high capital cost of electrifying lines, i.e. installation of catenary, substations, transformers, etc. These high costs necessitate large volumes of traffic; therefore, rail electrification may be limited to high volume routes (II-16).

The energy efficiency of an electric generating plant is similar, however, to that of the diesel-electric locomotive. That is, a diesel engine located in a locomotive exhibits a similar energy efficiency (about 35 percent) as an oil-fired thermal electric plant. However, if the electric energy is generated from nuclear or hydro sources then it is possible to substitute a non-petroleum fuel for current use of diesel fuel by rail.

To give an indication of the amount of electric energy that would be required in electrified rail use, forecasts of future rail output are required together with estimates of the proportion of total traffic which would be carried on electrified routes. This applies to both rail passenger and freight. For instance, the most likely route for electrification is Toronto-Montreal. In 1974 approximately 300 million passenger miles of the 765 million inter-city rail passenger miles in Ontario were on the Ontario portion of the Toronto-Montreal route. Consequently the hypothesis that thirty-nine percent of the passenger rail

output is met by electric energy might be used. The current energy use to output by rail operations in Ontario is calculated as 4,236 Btu's of diesel fuel per passenger mile in passenger service, at an estimated 43 percent load factor, and 625 Btu's per net ton-mile for freight service (see Chapter III, 4.1, (a)). Assuming a 35 percent efficiency for the diesel-electric locomotive in the production of electric energy, the above energy intensities translate to an electric energy output of 1,575 Btu/ passenger mile or .46 kwh/passenger mile and 2.8 Btu's per net ton-mile or 0.064 kwh/ton-mile. The amount of electric energy per unit of output that would need to be delivered to an electric locomotive is estimated to be in this same order - namely 0.46 kwh/passenger mile and 0.064 kwh/net ton-mile.

4.5 Sensitivity to Modal Shifts

The sensitivity of energy demand to inter-city passenger modal shifts can be easily tested. If for example, the intent was to analyze the fuel use impact of taking 10 percentage points off the automobile modal share and adding this amount to the bus mode, say beginning in 1980, simply adjust the passenger mile forecasts of the two modes accordingly and apply the energy use forecasting methodologies described above to these new totals. The total fuels use forecasts of the auto and bus modes so determined is then compared to the previous total estimated fuel use so as to calculate the impact of the modal shift.

B. URBAN PASSENGER SECTOR

1. Introduction

Urban areas have been defined, for the purpose of this analysis, as being the same as Ontario's nine CMA's (see Table II-2). Traffic patterns in these population centres of 100,000 or greater are considered to produce usual urban traffic flows typified, for the auto mode, by much commuter travel together with considerable cold start and stop and go driving, and secondly by the fact that all such centres support significant public transportation systems. By definition, then, centres of less than 100,000 population fall into the non-urban category. This division is of particular significance where the urban to non-urban split is used as the basis of calculating the output of urban and inter-city automobile passenger miles (see Table II-1, footnotes to Columns 4 & 5).

Transportation output statistics in this category, as in the others, run the short gamut from being poor to non-existent. Much time was spent estimating historical series; this is not to suggest however that the resulting figures are to be viewed as definitive. A considerable data collection program will have to be instituted if the reliability of the data is to be improved. This same observation applies to some of the explanatory variables used to formulate the transportation and modal share equations.

2. Transportation Demand

2.1 Historical Data

(a) Transportation Output - Automobile

Urban automobile passenger mile estimates for the years 1955 to 1974 are shown in Table II-22. These passenger mile figures were calculated concurrently with the inter-city automobile output figures as described in Table II-1.

(b) Transportation Output - Public Transit Modes

Historical transit data were separated into three categories, surface transit (including bus and trolley), subway (the Toronto subway system), and GO transit.

(i) Surface Transit Output

Transportation output by the surface transit mode in Ontario has declined absolutely since 1955 (Table II-18); the 1975 ridership is about 15 percent lower than in 1955. Toronto surface transit passenger miles declined from 948 million in 1955 to 840 million in 1975 (decline of 11.5 percent) while outside Toronto passenger miles declined from some 675 million in 1955 to 539 million in 1975 (decline of 20.2 percent).

(ii) Subway Transit Output

Subway transportation output in Toronto increased four times over the twenty year period 1955 to 1975 (Table II-19). Ridership increases seem to

be largely associated with expansions to the system rather than due to increasing utilization of existing sections; in 1956 the subway system had 134 cars* which increased to 422** cars by 1974 (increase of 3.14 times).

(iii) GO Transit

GO transit is a commuter rail and bus system centred in Toronto. Though it extends from Hamilton on the west to Oshawa on the east and Barrie to the north, it will be discussed under the urban passenger category as the primary aim of the system is to provide an alternative to the automobile for commuting to and from work.

The rail system from Oakville to Pickering was introduced in 1963; highway bus commuter services from localities east, west, and north of Metro Toronto commenced in 1970. In 1975 total ridership accounted for about 0.5 percent of all Ontario urban passenger miles; GO transit output estimates for the 1968-1975 period are shown in Table II-20.

(iv) Total Public Transit Output

Total Ontario public transit output figures for the historical period 1955-1975 are shown

* *SC 53-216.*

** *Information from S. Mozes, Statistics Canada.*

in Table III-22. Total ridership declined steadily from 1955 to 1962; since that time it has increased slowly to a 1975 total of 2.4 billion passenger miles which is only some 30 percent greater than 1955 output.

The Metro Toronto system is predominant in the province. In 1975 approximately 75 percent of all passenger miles were produced by the Toronto system (78 percent if the GO system is added to Toronto's total); in 1955 about 63 percent of passenger miles were travelled in the Metro Toronto system.

Transit transportation output data from 1972 onwards, since the inception of Ontario's transit subsidy program, can be expected to be of higher quality than for earlier years. All municipalities since 1972 have been required to submit detailed reports covering their financial and operating statistics.

(c) Transportation Output - Taxi

Taxi-cab passenger miles account for 1 to 2 percent of urban passenger miles in Ontario (Table II-21 and II-22). Taxis are one of the so-called para-transit modes which include:

- daily and short term rental cars
- taxicabs
- dial-a-bus
- car-pools
- subscription bus sytems

Para-transit modes are defined as small vehicles systems

designed to operate directly in response to demand without fixed schedules or routes except where they are pre-arranged as in car pools and subscription bus operations.

Dial-a-bus and subscription bus systems have not been identified in this analysis; to date their contribution to urban passenger travel has been very small. Rental cars and cars used by car pools are included insofar as their numbers are included in the auto registration totals which are the basis of estimating inter-city and urban auto passenger miles.

(d) Transportation Output - Urban Total

Table II-22 summarizes Ontario urban passenger output for the period 1955 to 1974. The automobile is by far the most important urban transportation mode and has become increasingly more important over this period; currently over 92 percent of all urban travel is by the automobile.

All passenger mile data is suspect. The automobile output totals are based on uncertain assumptions concerning annual miles per vehicle, the split between urban and non-urban vehicle miles per automobile, and the average number of passengers per vehicle mile; varying any of these could significantly alter the totals. Transit passenger mile estimates required that assumptions be made concerning the number of transfer passengers and the average trip distances of passengers; fare paying passenger information is available and assumed to be of reasonable quality. Taxi output figures are based on uncertain assumptions concerning the number of registered taxis, average vehicle miles per taxi, and passengers carried per vehicle mile. The development of data collection programs to improve the quality of the

data is a general requirement which applies to all passenger modes.

Urban passenger miles of service provided by school buses have not been identified. The urban charter bus category has been imperfectly accounted for by including charter bus passengers as reported by Statistics Canada in the surface transit bus totals which were then multiplied by average trip distances typical of transit bus journeys; as such charter bus output will be underestimated.

TABLE II-18

SURFACE TRANSIT TRANSPORTATION OUTPUT - ONTARIO,

1955 - 1975

Year	Fare Paying Surface Transit Passengers (1)	Average Trip Length (2)	Surface Transit Passenger Miles (3)
	(000,000)	(miles)	(000,000)
1955	464	3.5	1,624
1956	445	3.5	1,557
1957	423	3.5	1,480
1958	407	3.5	1,425
1959	402	3.5	1,407
1960	389	3.5	1,361
1961	365	3.5	1,278
1962	369	3.5	1,291
1963	365	3.5	1,278
1964	368	3.5	1,288
1965	384	3.5	1,344
1966	378	3.5	1,323
1967	381	3.5	1,333
1968	374	3.5	1,309
1969	366	3.5	1,281
1970	357	3.5	1,250
1971	358	3.5	1,253
1972	373	3.5	1,305
1973	359	3.5	1,256
1974	375	3.5	1,312
1975	394	3.5	1,379

FOOTNOTES TO TABLE II-18

(1) *Surface Transit Passengers*

(a) *Total fare paying passengers 1955 to 1960 from SC 53-003. Subway passengers as reported in SC 53-216 deducted from total to yield bus and trolley totals.*

(b) *1961 to 1968 figures from SC 53-216; figures reported are for systems earning gross annual revenue in excess of $20,000.*

(c) *1969 to 1972 from SC 53-003. Figures reported are for systems earning gross annual revenue in excess of $100,000. This represented 26 systems in 1969, 1970, 1971 and 25 systems in 1972.*

(d) *Total fare paying passengers for 1973 to 1975 from the Ontario Ministry of Transportation & Communications (Mr. D. Garner) for all centres with populations in excess of 45,000; 25 systems, including Toronto, are in this category. Subway revenue passengers were deducted from these totals to obtain bus and trolley passengers.*

(2) *Average Trip Length*

(a) *Estimates of current average bus trip length from Mr. W. Frost of the Toronto Transit Commission is 3.3 miles; this does not include transfer distances travelled on the subway by bus or trolley riders. Mr. Frost is of the opinion that surface and subway average trip distances have been increasing over time as service has been extended to suburban areas.*

(b) *Average bus trip length in the U.S. for 1971 for all areas has been estimated at 3.7 miles:*

Urban Population (000)	*Average Trip Length (miles)*
2,000 and over	*3.5*
1,000 to 2,000	*4.4*
500 to 1,000	*4.1*
250 to 500	*3.5*
100 to 250	*3.6*
50 to 100	*3.0*
Average, all areas	*3.7*

SOURCE: U.S. Department of Transportation, 1974 National Transportation Report, July 1975, p. 262.

FOOTNOTES TO TABLE II-18 (Cont'd)

(c) *D.J. Reynolds in a report, The Urban Transport Problems in Canada, 1970-2000, estimates an average urban bus trip in Canada at 4.2 miles (Appendix 3, p. 103).*

(d) *An average trip length of 3.5 miles will be used in estimating passenger miles. This ratio will be assumed constant over the historical period.*

(3) Passenger Miles

(a) *The intent is to develop passenger mile figures for surface transit systems operating in the nine Ontario CMA's (Table II-2), which will correspond to the passenger mile estimates made for urban autos and taxis (Table II-29). The passenger mile figure obtained by multiplying the fare paying passenger column by 3.5 will slightly overestimate passenger miles travelled in CMA's as the passenger figure includes passengers carried in some smaller centres as well (in 1973 passengers carried in the nine CMA's represented 93 percent of all passengers carried in communities of greater than 45,000 population). Conversely, the passenger mile figure will be underestimated because passenger miles of passengers transferring onto the bus or trolley system from the subway in Toronto are not accounted for. These effects are assumed to balance one another so the passenger mile figure is calculated as the product of fare paying passengers by average trip length.*

TABLE II-19

SUBWAY TRANSPORTATION OUTPUT - ONTARIO,

1955 - 1975

Year	Fare Paying Passengers (1)	Multiplier (2)	Fare Paying and Transfer Passengers (3)	Average Trip Length (4)	Passenger Miles (5)
	(000,000)		(000,000)	(miles)	(000,000)
1955	35	2.0	70	3.0	210
1956	36	2.0	72	3.0	216
1957	37	2.0	74	3.0	222
1958	36	2.0	72	3.0	216
1959	36	2.0	72	3.0	216
1960	35	2.0	70	3.0	210
1961	33	2.0	66	3.0	198
1962	33	2.0	66	3.0	198
1963	36	2.0	72	3.1	223
1964	38	1.9	72	3.2	230
1965	41	1.9	78	3.4	265
1966	67	1.8	121	3.6	435
1967	76	1.8	137	3.8	521
1968	89	1.8	160	3.8	608
1969	95	1.8	171	4.0	684
1970	98	1.8	176	4.0	704
1971	101	1.8	182	4.0	728
1972	105	1.7	178	4.2	748
1973	106	1.7	180	4.2	756
1974	109	1.7	185	4.2	777
1975	118	1.7	201	4.2	844

FOOTNOTES TO TABLE II-19

(1) *Fare Paying Passengers*

- (a) *1955 from Toronto Transit Commission*
- (b) *1956 to 1960 from SC 53-003*
- (c) *1961 to 1968 from SC 53-216*
- (d) *1969 to 1972 from SC 53-003*
- (e) *1973 to 1975 from Toronto Transit Commission.*

(2) *TTC estimate currently that total passengers carried by the subway systems, including those who transfer on from bus or trolley, is 1.7 times the number of fare paying passengers. Similarly, they estimated the figure in 1955 at 2.0. Resourcecon have used their own judgement to decline the multiplier between 1955 and 1975; reductions have been made to reflect major expansions in the subway system.*

(3) *Column 1 X Column 2*

(4) *Average trip length of 4.2 miles per passenger (including both fare paying and transfer passengers) is TTC's current estimate of distance travelled. Resourcecon have used their own judgement to reduce this trip length figure in earlier years to correspond to the shorter length of subway system.*

(5) *Column 3 X Column 4*

TABLE II-20

GO TRANSIT TRANSPORTATION OUTPUT

1968 - 1975

(000,000 pass. mi.)

Year	Rail (1)	Bus (2)	Total
1968	72.0	-	72.0
1969	75.2	-	75.2
1970	81.6	14.5	96.1
1971	91.5	44.5	136.0
1972	103.1	50.4	153.5
1973	93.1	53.8	146.9
1974	114.5	51.3	165.8
1975	120.3	55.0	175.3

(1) Rail passenger miles of service from Toronto Area Transit Operating Authority for 1971 to 1975 inclusive. Figures for 1968, 1969, and 1970 based on passenger totals estimated by TATOA *multiplied by 16 miles per passenger trip. The 1973 reduction in ridership is attributed to a rail strike.*

(2) Bus passenger miles obtained from passenger totals for each year as compiled by TATOA multiplied by an arbitrary 15 miles per passenger trip. The 1974 reduction in ridership is attributable to a bus strike.

TABLE II-21

TAXI TRANSPORTATION OUTPUT - ONTARIO,

1955 - 1974

Year	Number of Taxis (1)	Vehicle Miles (2) (000,000)	Passenger Miles (3) (000,000)
1955	3,139	220	248
1956	3,243	227	255
1957	3,404	238	268
1958	3,539	248	279
1959	3,653	256	288
1960	3,764	263	296
1961	3,863	270	304
1962	3,957	277	312
1963	4,063	284	320
1964	4,184	293	330
1965	4,316	302	340
1966	4,490	314	353
1967	4,627	324	365
1968	4,747	332	374
1969	4,852	340	383
1970	4,971	348	392
1971	5,072	355	399
1972	5,151	361	406
1973	5,192	363	408
1974	5,264	368	414

FOOTNOTES TO TABLE II-21

(1) *Average taxi cab population of 1.0/1000 assumed in Ontario CMA's, based on information in Canadian Taxi Survey (DOE, 1974) pp. 9-12. Number of taxis was therefore derived by dividing populations of nine Ontario CMA's by 1000.*

(2) *Average annual vehicle miles per taxi over whole historical period estimated at 70,000 miles based on Canadian Taxi Survey, pp. 14-16.*

(3) *A study by N.D. Lea & Associates in Montreal (Taxi Industry Statistics - Montreal, 1974) showed paid mileage as a percentage of total mileage to be about 70 percent: Canadian Taxi Survey, 1974, p. 26. In the United States paid mileage is estimated at no more than 50 percent of total mileage. For Ontario, where the number of cabs per capita are estimated at a relatively low figure of 1.0/1000, the ratio of paid mileage to total mileage will be assumed as 0.75. It will be further arbitrarily assumed that the average number of passengers per fare is 1.5. On this basis the average number of passenger miles per vehicle mile is estimated at 0.75 X 1.5 = 1.125.*

TABLE II-22

URBAN PASSENGER OUTPUT - ONTARIO, 1955 - 1974

(000,000 passenger miles)

Year	Auto		Surface Transit		Subway		GO Transit		Taxi		Total	Subway and Surface Transit and GO Transit
	PM	% Total	PM	% Total	PM	Total	PM	% Total	PM	% Total	PM	
1955	12,259	85.5	1,624	11.3	210	1.5	-	-	248	1.7	14,341	1,834
1956	13,119	86.6	1,557	10.3	216	1.4	-	-	255	1.7	15,147	1,773
1957	13,691	87.4	1,480	9.5	222	1.4	-	-	268	1.7	15,661	1,702
1958	14,715	88.5	1,425	8.6	216	1.3	-	-	279	1.7	16,635	1,641
1959	15,800	89.2	1,407	7.9	216	1.2	-	-	288	1.6	17,711	1,623
1960	16,543	89.9	1,361	7.4	210	1.1	-	-	296	1.6	18,410	1,571
1961	17,317	90.7	1,278	6.7	198	1.0	-	-	304	1.6	19,097	1,476
1962	17,847	90.8	1,291	6.6	198	1.0	-	-	312	1.6	19,648	1,489
1963	18,390	91.0	1,278	6.3	223	1.1	-	-	320	1.6	20,211	1,501
1964	19,538	91.4	1,288	5.9	230	1.1	-	-	330	1.5	21,386	1,518
1965	20,917	91.5	1,344	5.9	265	1.2	-	-	340	1.5	22,866	1,609
1966	22,167	91.3	1,323	5.4	435	1.8	-	-	353	1.5	24,278	1,758
1967	23,072	91.2	1,333	5.3	21	2.1	-	-	365	1.4	25,291	1,854
1968	23,174	90.7	1,309	5.1	608	2.4	72	0.3	374	1.5	25,537	1,985
1969	25,827	91.4	1,281	4.5	684	2.4	75	0.3	383	1.4	28,250	2,040
1970	27,179	91.8	1,250	4.2	704	2.4	82	0.3	392	1.3	29,607	2,036
1971	29,057	92.0	1,253	4.0	728	2.3	136	0.4	399	1.3	31,573	2,117
1972	30,723	92.2	1,305	3.9	748	2.2	154	0.5	406	1.2	33,336	2,207
1973	31,656	92.5	1,256	3.7	756	2.2	147	0.4	408	1.2	34,223	2,159
1974	31,829	92.3	1,312	3.8	777	2.3	166	0.5	414	1.2	34,498	2,256
1975	-	-	1,379	-	844	-	175	-	-	-	-	2,398

SOURCE: Tables II-1, II-25, II-26, II-27, II-28.

2.2 Explanatory Variables

The selection of the variables used to explain urban passenger transportation demand benefitted to a significant extent from previous work done in the inter-city passenger sub-sector. Yet the actual series themselves reflect, so far as proved possible, the specific nature of the Ontario urban passenger market. Following is a brief discussion of each of the variables which have been selected; the historical values of these variables are presented in Table II-23.

(i) Personal disposable income statistics for urban areas only can be approximated by using taxation statistics on a county basis (OS, Table II-17) and then dividing by the appropriate regional or provincial CPI. Since with the available Statistics Canada information this method would necessarily include non-urban portions of predominately urban counties, the more simple measure of personal disposable income, allocated on the basis of the annual Ontario urban/rural population split, has served as the basis of our estimation. This ratio was then adjusted upwards to take account of the fact that average urban incomes are higher than are average non-urban incomes. (Note that our operational definition of "urban" is not that of Statistics Canada but is instead based on changes in the relative populations of the CMA's).

(ii) Transportation price index reflects the relative passenger fare changes in each mode, and is again deflated by the CPI. It was developed using

TABLE II-23

INDEPENDENT VARIABLES - URBAN PASSENGER TRANSPORTATION DEMAND

Year	(1) $Millions PDY	(2) TPI	(3) % x 10 SUB
1955	5,336	106	418
1956	5,725	104	430
1957	6,084	108	442
1958	6,408	107	454
1959	6,716	107	466
1960	6,917	106	478
1961	7,039	106	490
1962	7,548	103	498
1963	7,980	101	506
1964	8,405	101	514
1965	9,005	102	522
1966	9,726	101	530
1967	10,318	101	538
1968	10,940	99	546
1969	11,614	98	554
1970	12,157	99	562
1971	13,121	100	570
1972	14,091	97	578
1973	14,744	92	585
1974	15,414	91	592

(1) Real personal disposable income, urban areas.

(2) Transportation price index.

(3) Suburbanization index.

Statistics Canada estimates of the price of urban transportation in Canada. The index for local transportation has been subdivided into component indices for local transit and for taxis, and although it is available only on a national basis, spot checks using the limited price information which is available provincially indicate that the relevant national and provincial responses are similar.

(iii) Suburbanization ratio presents a rough measure of the changing distribution of the urban population by comparing (for the Ontario CMA's only) the percentage of the population living in suburban areas to that living in central city regions (OS, Table 2.14). The general trend toward increasing suburbanization is prominently exhibited in this series, although it must be stressed that no such movement is apparent for certain of the cities that were included (such as Thunder Bay or London).

2.3 Forecasting Model

(a) Introduction

This section presents a further development of the basic one-stage linear least squares estimation procedures, and seeks to provide further insight into the scope and use of the modelling procedure.

(b) Discussion of Results

The final model of the urban passenger sub-sector, as

described in Table II-24, utilizes only personal disposable income and the suburbanization ratio to explain changes in urban passenger transportation demand for all modes from 1955-74. For both coefficients the signs are as expected, and the explanatory value of the aggregate equation - supported by both the large F statistic and an R^2 of .996 - is unusually high. The t-statistics are also highly significant on both of the variables, particularly urban income. But it should be stressed that a consistently low t can also represent a significant conclusion: price, for example, has consistently proven to be insignificant when used in this equation, a finding that serves to underscore the commonly held view that urban passenger output is not particularly sensitive to incremental changes in the prices charged for urban passenger modes. If, then, there were a desire to decrease total urban passenger miles travelled, either other discretionary instruments besides price changes should be utilized or the contemplated fare increases should be significantly larger (in real terms) then they have been historically. Otherwise, it would appear, service-related influences or increases in personal income quickly mask the effect of price increases. Finally, the Durbin-Watson statistic of 1.37 indicates that, at the 5 percent level of significance, no autoregression is present.

The model indicates that an increase in total urban income of one million dollars will, at the mean, result in a demand for an additional 1.74 million passenger miles, whereas a downwards shift in the urbanization index of only .1 percent - stimulated, perhaps, by redevelopment of downtown areas - could save more than twenty-one million passenger miles.

Other variables might have been useful in increasing the forecasting potential of this equation. Unfortunately, the

TABLE II-24

REGRESSION MODEL: TRANSPORT DEMAND, URBAN PASSENGER

General Form of Transportation Demand Model:

TRD = f (PDY, SUB)

where

TRD = urban passenger transportation demand (in passenger-miles)

PDY = personal disposable income

SUB = suburbanization index

Basic Equation:

$$TRD = a_0 + a_1 (PDY)_t + a_2 (SUB)_t$$

-4079	1.74	215.0
(-1.54)	(14.25)**	(2.95)**

R^2 = .996

F = 1906

DW = 1.37

** *Significant at the .05 level.*

impact of major technical innovations such as the "wired city" cannot be estimated from time-series studies carried out over a period preceding the mass introduction of the innovation. No doubt lower prices for communications services would make them a more acceptable substitute for some types of urban passenger trips, but the potential of this substitution cannot be assessed in quantitative terms.

3. Modal Shares

3.1 Historical Data

Table II-22 shows the historical shares of urban passenger transportation output by mode for the period from 1955 to 1974. The modal share equations for auto and transit (which include subway, bus, and trolley) were estimated separately utilizing the following three types of explanatory variables (for historical values see Table II-22).

(i) Relative price indices are based on national Statistics Canada indices (SC 62-002) for urban transit and for auto; the series used express annual relative changes in the modal prices which are charged.

(ii) Service quality indices for both auto and transit are extremely important in accounting for modal shifts. The inclusion of a service-type variable provides an obvious demonstration of the diff-iculties involved in using a time series model, since clearly much of what is most important simply cannot be converted into easily measurable series. At the same time, however, it should not be forgotten that, at the very least, the use of

TABLE II-25

INDEPENDENT VARIABLES - MODAL SHARES, URBAN PASSENGER

	Relative Price Indices		Service Quality (miles)	(veh/m)	
Year	Transit	Auto	Transit	Auto	AFY
1954	65	-	178	1,090	4450
1955	64	156	173	1,085	4490
1956	70	143	166	1,139	4545
1957	69	145	161	1,080	4600
1958	69	144	152	1,106	4690
1959	79	134	143	809	4780
1960	76	131	143	821	4897
1961	76	132	141	791	5014
1962	78	129	140	709	5434
1963	81	123	144	706	5855
1964	81	124	139	779	6275
1965	85	117	137	804	6696
1966	85	118	149	828	7006
1967	99	101	146	871	7316
1968	99	101	153	885	7642
1969	113	89	153	857	7968
1970	112	89	145	810	8294
1971	108	92	140	817	8620
1972	107	94	148	822	8950
1973	102	98	163	806	9453
1974	94	107	176	798	9960

a defensible proxy should allow a comparison of the explanatory significance of different variables to be made, and may provide a useful key to the relative effectiveness of various social policy options.

The proxies which have been developed were, for auto, a measure of the registered urban autos per mile of urban road (SC 53-201) and, for transit modes, a variable expressing average per-capita vehicle miles run (SC 53-216). It is thought that the decline in the auto measure reflects the increasing trend toward suburbanization, while the sharp drop between 1958 and 1959 could reflect changes in municipal boundaries. It should be noted that the development of alternative service quality measures was attempted - such as, for example, an auto variable which would reflect the lane miles of urban road constructed and, for transit, an annual series measuring the percent of the population within 1000 feet of a transit stop - but the dual constraint imposed by the need for consistent time series data proved impossible to overcome.

(iii) <u>Average family income, Ontario</u> has been computed on the basis of Statistics Canada data for Ontario (SC 13-528, 13-538, 13-544). For the early years the information was collected only infrequently and hence some extrapolation was required.

3.2 Forecasting Model

(a) Introduction

Separate series were developed for the transit and auto modes; the results of both equations are discussed here and presented in Table II-26. Note that two equations are presented for the transit mode; in this case the explanatory power of the first (four variable) equation is higher, but the addition of the final family income and service quality variables effectively robs the relative price measure of its significance. The transit equations are lagged by one year.

(b) Discussion of Results

This set of modal share equations is of better quality than are those for the inter-city passenger market. All variables except price have the expected sign (so that an increase in price, a decrease in transit vehicle miles run per capita, or an increase in the number of urban autos per mile of urban road, will result in a loss of passenger miles) and are highly significant. Price becomes significant in the four-variable transit equation but average family income (which is correctly negative: an increase in income favours the auto over the transit modes) and both service quality variables retain their strong explanatory value.

Note that the signs on the two service quality measures are correctly the same in each equation, since the auto measure is really an inverse: as the number of autos per mile of road increases, we would expect relative transport demand for the auto modes to decrease. Hence in the two equations which examine the auto mode this variable bears a correctly negative sign. Yet when this auto information is carried in

TABLE II-26

REGRESSION MODEL: MODAL SHARES, URBAN PASSENGER

General Form of the Modal Shares Model:

$$\% \; UPM = f\,(RPI, SVA, SVT, AFY)$$

where

UPM = modal share of urban passenger transportation demand, (as a percent of total urban passenger miles)

RPI = relative price index

SVA = service quality, auto

SVT = service quality, transit

AFY = average family income

Basic Equation: Auto

$$UPM_A = b_0 + b_1 \; (SVA)_t + b_2 \; (AFY)_t + b_3 \; (SVT)_t$$

	b_0	$(SVA)_t$	$(AFY)_t$	$(SVT)_t$
	980	-0.05	.007	-0.52
	(67.1)	(-3.97)**	(9.31)**	(-3.81)**

R^2 = .95
F = 102.
DW = 1.63

Basic Equation: Transit

$$UPM_T = b_0 + b_1 \; (RPI)_{t-1} + b_2 \; (SVT)_{t-1} + (AFY)_{t-1} + b_4 \; (SVA)_{t-1}$$

	b_0	$(RPI)_{t-1}$	$(SVT)_{t-1}$	$(AFY)_{t-1}$	$(SVA)_{t-1}$
	-27.7	0.07	.77	-0.006	.028
	(-1.23)	(.31)	(4.29)**	(-2.75)**	(1.74)**

R^2 = .94
F = 55.2
DW = 1.55

Cont'd.

TABLE II-26 Cont'd.

$$UPM'_T = b_0 + b_1 (RPI)_t + b_2 (SVT)_t$$

	b_0	b_1 $(RPI)_t$	b_2 $(SVT)_t$
	-6.37	-.61	.93
	(-0.24)	(-5.82)**	(6.38)**

R^2 = .87
F = 57.9
DW = 1.52

** *Significant at the .05 level.*

the transit equation we would expect the opposite (and hence positive) sign, since a relative decrease in the auto mode creates, by definition, an increase in the percentage share carried by transit.

4. Energy Use Forecasts

4.1 Automobile Mode

(a) Forecasting Methodology

Forecasts of urban passenger miles will be produced by the above described transportation demand and modal share equations. Energy use by the auto mode can then be calculated by the application of the methodology outlined in Section A.4.1(a), dealing with inter-city automobile fuel use.

(b) Sensitivity Analysis

The discussion of the impact on auto fuel use of various changes in technology, load factor, or operating conditions, as presented in Section A.4.1(c) dealing with inter-city auto, apply to the urban auto mode. The following additional comments, particularly applicable to urban auto use, can, however, be made:

(i) Drag Coefficients:

Lowering the aero-dynamic drag of automobiles, as discussed in Section A.4.1(c) above, will have little effect on urban auto fuel use because of the lower average speeds at which autos typically travel in urban areas.

(ii) Electric Automobiles:

The electric automobile is often discussed as a primarily urban vehicle which would be energy efficient (largely because of the small size of vehicle which is envisaged) and

which would not contribute to air pollution in urban areas. The electric energy requirement at the wheels for an electric compact (approximately 2,000 lbs.) has been estimated at approximately 0.25 kwh/mile (II-17, 43); using a vehicle system efficiency of 0.47 (II-18, 61) (the series product of 0.87 for battery charge, 0.80 for battery discharge, and 0.67 for operation of motor and controls), the electric energy requirement at the point of charging the batteries would be 0.53 kwh/mile. Assuming an electric energy from fossil fuels at an efficiency of 34 percent* the primary energy requirement would be 5,300 Btu's per mile. This compares to 6,000 Btu's per mile for a mini-size (Honda) internal combustion auto achieving an urban fuel use efficiency of 25 mpg.**

Consequently, the energy efficiency of the electric automobile is similar to that of a similar sized internal combustion automobile assuming the electric energy is generated from fossil fuels. However, if the electric energy is generated from hydro or nuclear sources, it is possible to substitute a non-petroleum fuel for the current gasoline use.

A technological breakthrough is still required in battery construction and operation before an electric urban auto can be expected to perform up to the standard of an equivalent sized combustion engine auto. Concerning the acceptance of the electric auto the point should be made

* *1 kwh (3,412 Btu's) output/10,000 Btu's input.*

** *Neither of these figures incorporates energy transmission and distribution losses or losses in the refining process.*

that it is a sub-compact vehicle; it can be expected that an equivalent internal combustion vehicle (e.g., a Honda Civic) would be highly competitive in terms of energy efficiency, performance, and range.

The energy use model can accommodate the introduction of the electric auto and only requires that assumptions be made concerning the proportion of the new vehicle fleet each year which will be electric (the same survival rates must also be assumed or the model modified to accept different rates for the electric auto). If urban use only of the electric auto is to be assumed (which would reduce its competitiveness with internal combustion alternatives) a different average annual mileage can be used (say 7,500 miles/auto) to the figure chosen for the internal combustion vehicles.*

(iii) Urban Operating Conditions:

Less congestion and smoother traffic flow will lead to less energy use per vehicle mile of auto use. However, a companion trend would be an increased level of travel by the auto mode

* *The model would require adjustment to accommodate different annual mileage and urban only travel assumptions for one class of vehicle.*

(most of it single passenger) which would tend to increase average urban fuel use per passenger mile in total.

4.2 Public Transit Modes

(a) Forecasting Methodologies

Passenger miles of public transit travel will be forecast using the transportation demand and modal share models. Subjective division of the public transit total among types of transit such as surface transit and subway will be made. These output figures will be multiplied by energy efficiency ratios of fuel use per passenger mile to obtain forecasts of energy use.

(b) Observed Energy Intensiveness

Energy use per passenger mile for main transit mode categories is shown in Table II-27. The factors for electric transit and bus transit are based on SC data for 1975. Comparable data for earlier years is unavailable, and disaggregation of subway, trolley and streetcar is not possible. In the case of bus transit, it was observed that 96.8 percent of energy requirements were derived from diesel oil and 3.2 percent from gasoline. It was not possible to obtain an energy intensiveness factor for GO Transit rail service. Consequently, a U.S. factor has been used; it indicates 1974 energy consumption of 286 trillion Btu's, all of which would have been derived from diesel oil.

(c) Sensitivity Analysis

The sensitivity of energy use to changes in technology,

TABLE II-27

ENERGY INTENSIVENESS FACTORS FOR PUBLIC TRANSIT MODES

MODE	ENERGY EFFICIENCY (Btu's per passenger mile)
Electric transit, Ontario(1)	702
Bus transit, Ontario(2)	2,848
Commuter rail transit(3)	2,493

(1) Based on aggregate energy consumption for subway, trolleys and streetcars in 1975 of 239,627,000 kwh. (817,607 million Btu's.) for an estimated transportation output of 1,165 million passenger miles (SC 53-003).

(2) Based on 1975 energy consumption of 3,011 billion Btu's (for 1,057 million passenger miles transportation output. The output estimate assumes an average trip length of 3.5 miles for 302,024,000 passengers (SC 53-003).

(3) U.S. Department of Transportation, "A Summary of Opportunities to Conserve Transportation Energy." August 1975, p. 4-4.

load factor, or operating techniques can be evaluated by calculating the effect of changes in these parameters on energy efficiency and multiplying transportation output by the revised energy efficiency values. The timing of the changes can be varied as desired.

(i) Load Factor:

The potential for energy saving from switching to the transit mode from the auto mode would be even greater if the low average load factors of 23 and 33 percent for the surface transit and subway modes respectively (Table II-28) could be improved. Some improvement could without doubt be achieved but urban transit load factors are limited by the substantial peaking characteristics of travel during morning and evening rush hours, and by the fact that even during peak hours, traffic is so unidirectional that back-hauls must be run at very low load factors. Improving the load factors on transit to any substantial degree would require not only increased patronage, but also changes in urban lifestyles such as varying work hours and increased residential densities.

The change in fuel use efficiency as a result of load factor changes can be simply calculated; if fuel use was not sensitive to passenger loading, increases in load factors would lead to directly proportional decreases in fuel use per passenger mile; fuel use efficiency would improve by the reciprocal of the percentage increase in load factor. Assuming fuel use to

TABLE II-28

LOAD FACTORS
SURFACE TRANSIT & SUBWAY
ONTARIO, 1975

	Passenger Miles (1)	Vehicle Miles (2)	Load Factor	Load Factor (3)
	(000,000)	(000)	(pm/vm)	%
Surface Transit	1,379	114,491	12.0	23.
Subway	844	33,970	24.8	33.

(1) Table II-29.

(2) SC 53-003.

(3) SC 53-216 (1970)

Surface transit seat miles 4,495 million
Surface transit veh. miles 85 million

Seat miles/veh. mile = 53.

Subway seat miles = 1,698 million
Subway veh. miles = 22.7 million

Seat miles/veh. mile = 75.

be to some degree sensitive to passenger loading, this fuel use efficiency should be calculated to change by some percentage, say 85 percent, of the proportionate change in load factor. A 10 percent increase in load factor would result in a fuel use efficiency improvement of $\frac{1}{1.+(.10x.85)}$.

(ii) Technological Change:

Modest improvements in bus engine and drive train components can be expected to improve fuel economy of urban buses. In the case of buses which are already dieselized, as is the case in Ontario, fuel economy gains of new buses by 1980 will be limited to less than 20 percent, according to a U.S. Environmental Protection Agency study (II-5, 94). Other than the greater use of diesel engines, the EPA analysis found the most significant short term pay off technology options to be:

- optimized cooling systems (including variable speed fan drives)
- radial tire
- engine power and speed derating

Some further analysis is required to develop energy use efficiency ratios for specific forms of technological change so that the energy impact of such changes can be assessed.

(iii) <u>Changes to Operational Procedures:</u>

Apart from technological improvements another option for developing better public transport system lies in improving the organization of transit systems using existing technology - e.g. dial-a-bus, computerized traffic controls, dedicated traffic lanes, etc. Some further analysis is required to see if energy efficiency improvements associated with such operational adjustments can be identified.

4.3 Sensitivity to Modal Shifts

The sensitivity of energy demand to urban passenger modal shifts can be easily tested. If for example the intent was to analyze the fuel use impact of taking 10 percentage points off the automobile modal share and adding this amount to the surface transit mode, say starting in 1980, simply adjust the passenger mile forecasts of the two modes accordingly and apply the energy use forecasting methodologies described above to these new totals. The total fuel use forecast of the auto and surface transit modes so determined is then compared to the previous total estimated fuel use so as to calculate the impact of the modal shift.

C. EXTRAPROVINCIAL AIR PASSENGER SECTOR

1. Introduction

Since the objective of this report is to concentrate on the demands which are and will be placed on available Ontario supplies of fuel, it is necessary to take account of trips to non-Ontario points if these journeys consume Ontario fuel. Passenger mile figures for extraprovincial flights could not be calculated. As a result the dependent variable used in the transportation demand equation is the statistic "number of departing passengers" from the principal Ontario airports to out-of-province destinations. The fuel loaded in Ontario by commercial airliners in extraprovincial travel has been calculated historically and related to the historical number of departing passengers. The fuel use per departing passenger relationship which is developed is then used as the basis of forecasting fuel demand in Ontario for out-of-province flights.

2. Transportation Demand

2.1 Historical Data

(a) Transportation Output - Extraprovincial Total

Table II-29 summarizes the relevant information on extra-provincial air passenger travel utilizing statistics on passenger origins and destinations which have been computed for each year since 1968 by Statistics Canada* and which were previously tabulated by the Canadian Transportation Commission. The total number of departing passengers

* *see the footnote to Table II-55.*

TABLE II-29

DEPARTING PASSENGERS[1], 5 MAJOR ONTARIO AIRPORTS[2]

	Total Number, Departing Passengers	Departing to Ontario Destinations[3]	Departing to Extra-Provincial Destinations
1955			
1956			
1957			
1958			
1959			
1960			
1961	721,155	487,891	233,264
1962	743,000	499,366	243,634
1963	773,350	514,698	258,652
1964	782,560	517,689	264,871
1965	901,445	586,375	315,070
1966	1,012,285	643,006	378,279
1967	1,194,175	753,810	440,365
1968	1,259,200	782,685	476,515
1969	1,407,535	851,385	556,150
1970	1,692,365	1,036,525	665,840
1971	1,782,335	1,083,562	698,773
1972	1,951,355	1,166,927	784,428
1973	2,463,885	1,447,831	1,016,054
1974	2,728,550	1,621,570	1,106,980

(1) Figures from 1968 tabulated from SC 51-204, Air Passenger Origin and Destination, Domestic Report. Prior to 1968, information was collected by the CTC.

(2) London, Ottawa, Thunder Bay, Toronto, Windsor.

(3) Particularly in the earlier years ('61-'68) for which this data was collected, often the only figure given was the total number of people travelling between the two points concerned. In such a case, the assumption was made that traffic volume was equally split - i.e., that the number of people travelling from A to B was equal to that travelling from B to A.

originating in the five major Ontario airports* has been divided into two components, those outgoing passengers bound for other Ontario points and those departing for extraprovincial (USA and other) destinations.

* *see footnote to Table II-29.*

2.2 Explanatory Variables

The selection of the independent variables has again benefitted from earlier work performed on other sectors; the modal share evaluation of inter-city transportation demand, for which an air passenger equation was developed, proved to be particularly helpful. The historical values of these variables are presented in Table II-30.

(i) Personal disposable income, Ontario has been deflated by the CPI for Toronto, for which 1961 = 100 (a CPI for Ontario is not available). In other runs similar aggregate measures (such as GNP and GPP) have been tried as well, since the level of Ontario extraprovincial air travel demand clearly depends to a great extent not only on the push-effect of the internal PDY but also on the pull of production levels and economic activity in other provinces.

(ii) Transportation price index has been developed based on Air Canada fares for 26 domestic city pairs, deflated by the annual CPI. The actual series used was an average of two separate indices developed for lengths of haul of 500 - 999 miles and 1,000 - 2,228 miles. This series is clearly not ideal in that it looks at all of Canada as well as at only domestic flights, but it appears to be the best available at the moment.

(iii) Population characteristics is a measure of the percentage of the population between 15 and 64 years of age (OS, Table 2.9), the range assumed to be the prime air travel years.

TABLE II-30

INDEPENDENT VARIABLES - EXTRAPROVINCIAL AIR PASSENGER

Year	(1) PDY	(2) TPI	(3) PCH
	$000,000		%
1955			
1956			
1957			
1958			
1959			
1960			
1961	10700	100	59.7
1962	11400	102	59.5
1963	12000	103	59.4
1964	12600	105	59.6
1965	13400	105	59.8
1966	14200	103	60.2
1967	15000	103	60.7
1968	15800	101	61.3
1969	16700	99	60.8
1970	17400	100	62.4
1971	18800	101	63.0
1972	20200	100	63.5
1973	21300	94	64.2
1974	22400	97	64.9

(1) Real personal disposable income.

(2) Transportation price index.

(3) Population characteristics.

2.3 Forecasting Model

(a) Introduction

The air transportation market has been the subject of extensive modelling in recent years, and the regression analysis results which are presented here are generally in tune with other findings. Two points should be noted. First, "extraprovincial air transport" is a very heterogeneous market which includes a large and disparate group of domestic and international routes. The selection of significant explanatory variables is therefore made more difficult. Secondly, the dependent variable (the number of departing passengers) which we have used is a bit unusual: where passengers are used to measure output it is customary to have a route-specific model or to include distance as an independent variable.

In the present instance neither of these approaches proved possible. As a result, we present the following information on price and income elasticities, which have been estimated in other studies, as a complement to our correlation analysis results which are shown in the succeeding section.

Author	Area	Price Elasticity	Income Elasticity
Brown and Watkins*	U.S.	- 2.4	+ 3.2
Quandt and Baumol**	California	- 1.3 to - 2.4	+ 0.4 to + 3.2
Lave***	U.S.	- 1.6	+ 2.8

* As reported in Lester B. Lave, "The Demand for Intercity Passenger Transportation," *Journal of Regional Science*, 12 (April, 1972), p.73

** *Ibid.*, p. 77.

*** *Ibid.*, p. 79.

Author	Area	Price Elasticity	Income Elasticity
Intercity Passenger Transport Study*	Windsor-Quebec Corridor	- 2.75	N.A.
Straszheim**	North	- 1.50	+ 2.04
	Atlantic	- 1.46 to - 1.75	+ 0.89 to + 2.32
	Transborder	- 0.71 to - 1.22	+ 0.84 to + 1.92
Verleger***	U.S.	generally -1.0	N.A.

It would appear from this research that long-run elasticities of + 2.0 with respect to per capita income and -1.5 with respect to airline prices might be appropriate. Projection efforts should reflect, roughly, these parameters.

(b) Discussion of Results

A major result of this three variable equation, as shown in Table II-31, has been to reconfirm the anticipated high explanatory value of the economic activity type of variable, in this case PDY. For example, an earlier step-wise regression (not shown) demonstrated that, for the most basic run of the dependent variable against only PDY, the very high R^2 of .96 was obtained. However, it should be noted these tests encountered quite severe problems of serial correlation, indicating that the effect of a disturbance which occurred in one period also exerted a strong influence on subsequent periods. Some

* *CTC, 1970.*

** *Mahlan Straszheim, The International Airline Industry (Washington: Brookings Institution, 1969), pp. 128 and 285. The elasticities reported here were estimated with Bayesian procedures.*

*** *P.K. Verleger, "Models of the Demand for Air Transportation," Bell Journal of Economics and Management Science, 3 (autumn,1972).*

TABLE II-31

REGRESSION MODEL: TRANSPORTATION DEMAND
EXTRAPROVINCIAL AIR PASSENGER

General Form of the Transportation Demand Model:

TRD = f (PDY, TPI, PCH)

where

TRD = extra provincial air passenger transportation demand (in number of departing passengers)

PDY = real personal disposable income

TPI = transportation price index

PCH = population characteristics

Basic Equation:

$$TRD = a_0 + a_1 (PDY)_t + a_2 (TPI)_t + a_3 (PCH)_t$$

	a_0	a_1	a_2	a_3
	-2335	.04	-12.76	57.3
	(-1.46)	(4.11)**	(-2.46)**	(2.53)**

R^2 = .99

F = 330.

DW = 1.68

** *significant at the .05 level.*

loss of efficiency and a bias in the estimated standard errors was therefore to be assumed.

For all variables the sign of the coefficient is as expected, and the t-statistics are significant in all cases. The relatively large coefficient on price emphasizes the importance of this factor; each one percent change in the index results in (at the mean) a loss of nearly 13,000 departing passengers, or about 4 percent of the total.

The degree of multicollinearity which is present in this equation appears to be small. In particular pair-wise relationships, however, such as that between PCH and PDY in the correlation matrix shown below* indicate the expected high degree of association.

	PDY	TPI	PCH
PDY	-1.000		
TPI	-0.727	1.000	
PCH	0.966	-0.795	1.000

* *Values close to 1.000 indicate a high degree of pair-wise association.*

3. Energy Use Forecasts

3.1 Forecasting Methodology

Fuel lifted in Ontario for extraprovincial air mode use will be forecast by applying energy use per departing passenger factors to the number of passengers forecast to travel from Ontario to extraprovincial destinations. These passenger forecasts will be produced by the transportation demand equations.

3.2 Historical Energy Use

Total fuel sales in Ontario to commercial air operations are reported in SC 45-208 Refined Petroleum Products ; these are shown for the years 1965 to 1974 in Table II-32. Estimates of fuel used in inter-city air travel between points in Ontario (plus passenger miles attributable to Ottawa-Montreal and Toronto-Montreal routings) are calculated by multpilying inter-city passenger mile figures (Table II- 3) by estimated energy intensiveness factors per passenger mile (Table II-32); deducting this figure from the total yields an estimate of total fuel lifted by Canadian and foreign airlines in Ontario for departures to extraprovincial destinations. During 1974 energy lift per extraprovincial passenger amounted to 20.17 million Btu's.* It may be assumed that virtually all energy was derived from aviation turbo fuel.

* *$22{,}330 \times 10^{9}$ Btu's $\div$ 1,106,980 passengers (Tables II-29 and II-32).*

TABLE II-32

PURCHASES OF FUEL IN ONTARIO FOR EXTRAPROVINCIAL AIR TRAVEL

	Total Fuel Sales to Commercial Carriers (1)			Fuel Consumed in Inter-City Air Travel			Fuel Lifted for Extraprovincial Air Travel	
	Av.Gas	Turbo Fuel (000 bbls.)	Btu's. (2) $\times 10^9$	Pass.-Mi. (3) (000,000)	Energy Use/ Pass.-Mi. (4) btu	Fuel Use Btu $\times 10^9$	Btu $\times 10^9$	% of Total Fuel
1965	71	1,766	9,913	530	9,400	4,982	4,931	50.0
1966	39	2,248	12,358	568	9,134	5,188	7,170	58.0
1967	38	2,765	15,151	675	8,867	5,985	9,166	60.5
1968	32	3,282	17,918	730	8,600	6,192	11,726	65.4
1969	42	3,528	19,298	818	8,333	6,816	12,482	64.7
1970	47	4,063	22,218	1,032	8,067	8,325	13,893	62.5
1971	18	4,171	22,656	1,060	7,800	8,268	14,388	63.5
1972	28	4,360	23,729	1,156	7,534	8,709	15,020	63.3
1973	27	5,116	27,814	1,406	7,267	10,217	17,597	63.3
1974	7	6,106	33,068	1,534	7,000	10,738	22,330	67.5

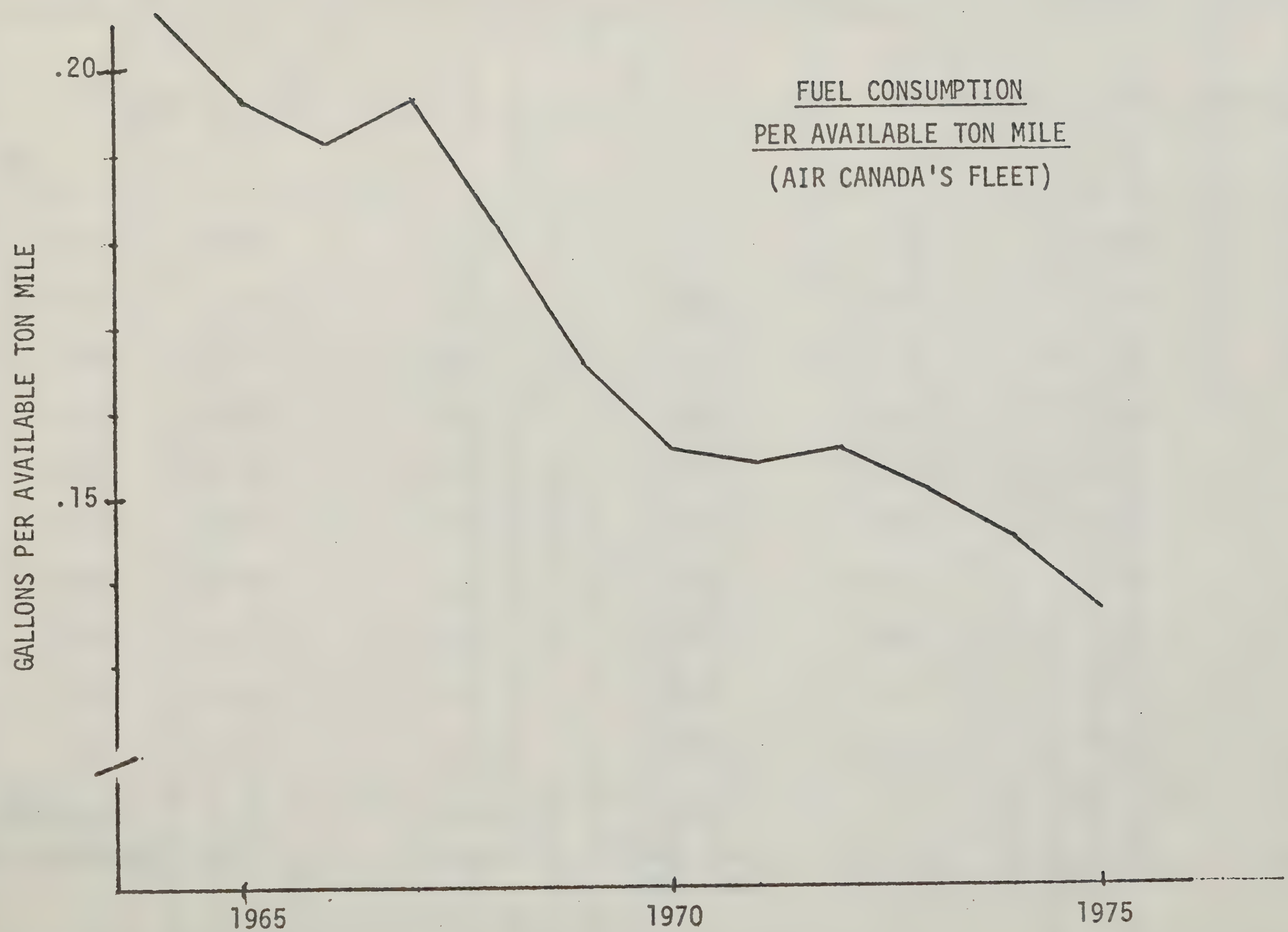
(1) *Table II-60.*

(2) *Btu conversion factors : aviation gasoline 5.05 million btu's./bbl. --- turbo fuel 5.415 million btu's./bbl.*

(3) *Table II-3.*

(4) *Energy Use per Passenger Mile: Energy use per passenger mile in 1974 estimated at 7,000 btu. Energy use per passenger mile in 1965 calculated at 9,400 btu based on Air Canada fuel use ratios in 1965 and 1974 shown in Figure II-5,ie. 7,000 btu's x* $\frac{\text{0.195 gals. per available ton mile}}{\text{0.145 gals. per available ton mile}}$ *= 9,400 btu's*
Energy use per passenger mile decreased in equal decrements from 9,400 btu's in 1965 to 7,000 btu's in 1974.

FIGURE II-5



SOURCE: Glenn, C.H., Possible Impact of Petroleum Shortages on Canadian Air Transportation. Paper prepared for presentation to the Institute of Combustion and Fuel Technology of Canada, Toronto, April 22/76. Mr. Glenn is vice-president fleet planning for Air Canada.

Most short haul air service in Ontario is proviced by Group I carriers employing stretch DC 9's, or Boeing 727's or 737's. Assuming average stage lengths in Ontario of 300 miles, the fuel use efficiency factor is in the order of one gallon to 37 seat-miles (Figure II-3). Assuming a load factor of 60 percent, this is equivalent to 6,969 Btu's per passenger mile (154,700 Btu's per gallon ÷ 22.2 passenger miles per gallon. Including the small proportion of passenger miles provided by non-Class I carriers, presumably at lower average load factors, an average 1974 energy intensiveness factor for Ontario will be higher than for the Group I carriers; a factor for 1974 of 7,000 Btu's per passenger mile is considered appropriate.

Air Canada have experienced a significant reduction in fuel use per unit of output (Figure II-5) over the 1965 to 1975 period; fuel use has decreased from about 0.195 gallons to 0.135 gallons per available ton-mile, a reduction of 30 percent. Applying this same change in energy use efficiency to all Ontario inter-city air travel, and the assumption of constant load factors over the period, forms the basis of calculating energy use per passenger mile ratios from 1974 (7,000 Btu's per passenger mile) back to 1965 (9,372 Btu's per passenger mile) Table II-32).

Because of the decrease in energy intensiveness factors, demand in Ontario has grown more slowly than the increase in transportation output.

Fuel sales associated with extraprovincial air travel account for about 65 percent of all commerical air carrier fuel sales in Ontario. Comparing airplane fuel purchases in Ontario and Quebec over the period 1971-74 (Table II-33) indicates proportionately more fuel being purchased in Ontario in 1974, presumably reflecting the loss of Quebec's historical fuel price advantage situation because of the major increase in international fuel prices in 1973.

TABLE II-33

COMMERICAL CARRIER FUEL SALES 1971-74

(000 bbls.)

	Aviation Gasoline			Turbo Fuel		
	Ont.	Que.	Canada	Ont.	Que.	Canada
1974	8	19	177	6,106	5,388	19,000
1973	27	29	204	5,116	5,310	17,069
1972	27	48	235	4,359	4,600	14,577
1971	18	26	247	4,170	4,351	13,751

SOURCE: SC-45-208

3.3 Sensitivity Analysis

The sensitivity of energy use in the extraprovincial air mode to changes in load factors, technology, or operating techniques will be evaluated by calculating the effect of each of these changes on energy use efficiency and multiplying transportation output by the revised energy efficiency values. The timing of the changes can be varied as desired.

TABLE II-34

FUEL USE BY COMMERCIAL CARRIERS, ONTARIO 1965 - 1974

('000 barrels)

	Aviation Turbo Fuel			Aviation Gasoline		
	Cdn. Airlines (1)	Foreign Airlines (2)	Total	Cdn. Airlines (1)	Foreign Airlines (2)	Total
1965	1,683	83	1,766	44	27	71
1966	1,915	333	2,248	35	4	39
1967	2,144	621	2,765	30	8	38
1968	2,548	734	3,282	29	3	32
1969	2,708	820	3,528	40	2	42
1970	3,305	758	4,063	46	1	47
1971	3,370	801	4,171	18	-	18
1972	3,495	865	4,360	27	1	28
1973	3,937	1,179	5,116	27	-	27
1974	4,758	1,348	6,106	7	-	7

SOURCE: SC 45-208.

(1) Includes all sales made in Ontario to all Canadian scheduled and non-scheduled passenger and cargo carriers in revenue Groups I to V (SC 51-202).

(2) Includes all sales made in Ontario to all foreign scheduled and non-scheduled passenger and cargo carriers.

The impact of load factor, seating density, technology and operating techniques are discussed below. Technology factors, etc. which are discussed in Section B.4.2(c), in the context of inter-city air travel, will be relevant here also.

(i) Load Factor:

Load factors of Canadian carriers operating flights averaged 63.1 percent in 1974. (Table II-35). Trans-border flights (those to the U.S., including Alaska & Hawaii) operated at the highest load factor (65.2 percent), and Pacific and Orient flights (Australia, Oceania, Asia) at the lowest (56.0 percent). Flights operating out of Ontario in 1974 (assuming few in the Pacific to Orient category) will be assumed to have operated at approximately 64 percent load factor. The 1974 energy lift of 20.17 million Btu's per departing passenger assumes a load factor of 64 percent. As was the case in the consideration of the inter-city air mode, it will be assumed fuel use efficiency will change by 85 percent of the reciprocal of the proportionate change in load factor.

(ii) Technological Factors:

Technological factors which will affect future aircraft fuel efficiencies are described in Section B.4.2(c). This discussion applies equally to the extraprovincial air mode.

TABLE II-35

LOAD FACTORS OF INTERNATIONAL FLIGHTS
OF CANADIAN CARRIERS, 1974

Route	Passenger Miles	Available Seat Miles	Load Factor (%)
	(000,000		
Trans-Border	1,988	3,029	65.6
Trans-Atlantic	3,586	5,590	64.2
Southern	908	1,569	57.9
Pacific & Orient	447	798	56.0
Total	6,929	10,986	63.1

SOURCE: SC 51-001.

(iii) Hydrogen Fuel:

Existing aircraft engines can be adapted to burn liquid hydrogen. Liquid hydrogen has about three times the energy content per pound as petroleum fuels, but occupies about three times the volume per unit weight. It is in the liquid state at about -250 degrees Celsius. A disadvantage of hydrogen relates to safety; it is a much more hazardous fuel than present petroleum fuels because of its ignition properties.

Hydrogen gas could be manufactured on a large scale by the electrolysis of water. In practice, the electrical energy of the hydrogen gas produced - about 150 kwh (512,000 Btu.) being required to produce 1,000 cubic feet (325,000 Btu.) of hydrogen gas. Hydrogen gas has been suggested as a long term alternative looking towards the inevitable day when fossil fuel supplies are exhausted; but over the next 30 years, at least, coal gasification and liquefaction will provide a much less costly and more convenient form of energy, unless there is a major breakthrough in hydrogen conversion technology.

III TRANSPORTATION FREIGHT SECTOR

For the purpose of forecasting future energy requirements for freight transportation it is convenient to divide the subject into three broad categories: inter-city freight for most commodities, inter-city freight for a few specified commodities, and urban freight (and some non-freight). This is the basis for division of this chapter into three major sections.

As a basis for forecasting, historical patterns in freight transportation are studied and documented. Despite many shortcomings in data and frequent requirements to extrapolate or indirectly derive historical information it is possible to establish relationships:

(i) between transportation output and socio-economic indicators;

(ii) between modal shares and socio-economic indicators;

(iii) between transportation output and energy consumption.

These relationships are the basis for much of the methodology which is developed for forecasting future energy requirements for freight transportation.

In each freight category the methodology which is developed allows preparation of a base case forecast of energy requirements to the year 2000. For the serious forecaster, this is only a first step in an attempt to predict, and possibly influence, the future. Subsequent to the base case forecast it is probable the forecaster will wish to examine the sensitivity of energy requirements to changes in transportation

technology, modal shares and independent socio-economic indicators. While the following descriptions frequently allude to examination of energy sensitivity, to a considerable extent it will be up to the forecaster to conduct sensitivity tests to meet his particular interests or requirements.

A. INTER-CITY GENERAL CLASS FREIGHT

1. Introduction

The inter-city General Class freight sector includes all freight commodities with the exception of grains, coal, iron ore, forest products, natural gas and oil.* General Class freight is considered in aggregate at all times and no attempt is made to identify any specific commodities in the class. Typically, volumes and movements in the class are considered to be the difference between all freight and the specific commodites identified above.

Forecasting of future General Class freight demand assumes an identifiable relationship between demand and a number of independent variables relating to national and regional socio-economic trends and changes. The relationship between output and socio-economic conditions is identified through multiple regression analysis of independent and dependent variables through a 20 year historical period: 1955 to 1974. General Class freight demand is forecast after trends or changes in future socio-economic conditions have been projected.

Three modes are considered for movement of General Class freight: rail, marine and highway, (all highway freight is included in the General Class),and an identifiable relationship is assumed between modal shares and socio-economic

* *"grains" includes SC classifications of wheat and all other grains; coal includes metallurgical and steam coal; iron ore includes iron ore and concentrates; forest products includes SC classifications of lumber, wood pulp and newsprint (excludes pulp wood); oil is primarily crude oil but includes other liquid petroleum products moved by pipeline.*

indicators. The relationship between historical modal output and indicators is identified through a multiple regression analysis similar to that used for relating transportation output and indicators. Future modal outputs are forecast from the regression equations after future socio-economic conditions have been projected.

Future energy requirements are a function of modal demand and energy intensiveness. For the rail and marine modes an historical evolution in energy intensiveness is documented, and for the highway mode assumptions are made on present energy intensiveness factors. Base case forecasting assumes continuation of present levels of energy intensiveness and fuel type split. Sensitivity analysis could include tests for the impact of continuation of historical trends towards decreasing energy intensiveness, substitution of fuel types, induced changes in modal energy intensiveness, changes in socio-economic indicator projections, and changes in modal shares.

It will be noted that no mention has been made of air freight. It is assumed that to a large extent air freight is ancilliary to air passenger service, and that forecasts of air passenger demand implicitly forecast an approximate (non-passenger related) air freight demand. The air freight energy requirement becomes a relatively constant "included overhead" on air passenger energy requirements. While this may not be the exact case, the difference would be inconsequential in comparison to total freight or total air passenger energy requirements.

2. Transportation Demand

2.1 Historical Transportation Output

(a) Transportation Output - Rail

Table III-1 summarizes General Class rail freight output in Ontario for the period 1955 to 1974. The procedure used to derive the series included the following steps:

(i) determination of typical mileages for rail freight movements across, into, out of, and wholly within Ontario;

(ii) calculation of total output for all freight commodities as the sum of products of tonnages moved multiplied by appropriate mileage factors;

(iii) calculation of the sum of outputs for all Specified Class commodities;

(iv) subtraction of the sum of outputs for Specified Class commodities from the total output for all freight commodities.

The difference between total output and the sum of Specified Class outputs is, by definition, the General Class output. A full explanation of sources and calculation procedures follows. Readers wishing to omit this portion of the report may turn to Section A.2.1 (b) Transportation Output - Marine.

TABLE III-1

GENERAL CLASS RAIL FREIGHT OUTPUT, ONTARIO

(000,000 ton-miles)

Year		Year	
1955	9,102	1965	18,745
1956	10,602	1966	18,919
1957	14,330	1967	17,361
1958	13,147	1968	18,647
1959	13,659	1969	17,575
1960	12,254	1970	20,201
1961	12,578	1971	20,488
1962	12,276	1972	22,392
1963	14,089	1973	24,909
1964	16,576	1974	25,411

Mileage factors used for calculation of rail freight output are shown in Table III-2. For movements across, into, and out of Ontario, mileages are based on the milepost listings which may be found in most railway company passenger time-tables, and knowledge of, or assumptions on, typical flow patterns for various commodities. Concentration of industrial activity between Toronto and Windsor lends support to the assumption that most movements into or out of the province terminate or originate between these points. For movements wholly within Ontario, calculations were made in order to obtain weighted average mileages for movements of each Specified class commodity and for the "all commodities" category. These were based on a complete compilation of relevant movements included in a 1972 CTC waybill analysis (III-1, 1A-88B). The assumption had to be made that the

weighted average mileages are applicable throughout the period of 1955 to 1974, as data are not available for other years, and, in any case, the compilation procedure is extremely time consuming.

TABLE III-2

MILEAGE FACTORS USED TO CALCULATE RAIL FREIGHT OUTPUT

Movement	Basis for Factor	Mileage Factor
across Ontario	average of CN and CP mainline mileages between the Manitoba and Quebec boundaries	1,086
Quebec to Ontario (Ontario to Quebec)	average of CN and CP mainline mileages between Hamilton and the Quebec boundary	328
Manitoba to Lakehead	average of CN and CP mainline mileages between the Manitoba boundary and Thunder Bay	347
Manitoba to Ontario (Ontario to Manitoba)	average of CN and CP mainline mileages between the Manitoba boundary and Hamilton	1,199
U.S.A. to Ontario (Ontario to U.S.A.)	average of CN mainline mileages from Brantford to Windsor, Sarnia and Niagara Falls	114
	exception: iron ore	35
within Ontario	weighted average mileage for movements of:	
	- grains	268
	- coal	113
	- iron ore	161
	- forest products	567
	- all commodities	165

Total rail freight output is shown in Table III-3. The series was based on CTC data; however, minor adjustments were required to obtain inclusion of less than carload (LCL) freight movements. The CTC source provides a volume record of freight flows to and from each province and the United States for a number of specific commodities, for "all other commodities", and for "all commodities" during the period from 1957 to 1972 (III-2, 228-311). By multiplying volumes moving through, into, out of, and wholly within Ontario by appropriate mileage factors, ton-mile output series were obtained as shown in Table III-4 and Tables III-30, 33, 36, 39. The CTC data excludes LCL movements, so an adjustment to each annual output figure was required to reflect these movements. On the basis of SC data, LCL multipliers were calculated for each year as the ratio of national carload plus non-carload revenue freight to carload revenue freight (III-3). The initial output series was then multiplied by the appropriate LCL multiplier to give the adjusted total rail output series.

Rail freight outputs for each Specified Class commodity, the totals of Specified Class commodities, and the totals for General Class commodities are shown in Table III-5. The General Class totals are the differences between the total rail freight outputs and the Specified Class totals. Calculation of output for Specified Class commodities followed the procedure outlined for calculation of the unadjusted total rail freight output series. For movements wholly within Ontario, appropriate mileage factors were used for the particular commodities concerned. As it may be assumed that Specified Class commodities all move in bulk form or in large shipments, no LCL correction factor is required.

TABLE III-3

TOTAL RAIL FREIGHT OUTPUT, ONTARIO

(000,000 ton-miles)

Year	Unadjusted Total	LCL Multiplier	Total
1955	na	-	15,970 est
1956	na	-	18,599 est
1957	24,218	1.012	24,509
1958	23,234	1.010	23,466
1959	23,833	1.009	24,047
1960	21,597	1.008	21,770
1961	21,685	1.008	21,858
1962	21,031	1.008	21,199
1963	23,222	1.006	23,361
1964	28,389	1.005	28,531
1965	27,777	1.006	27,944
1966	30,305	1.005	30,457
1967	28,506	1.003	28,592
1968	26,187	1.002	26,239
1969	25,874	1.001	25,900
1970	31,478	1.005	31,635
1971	32,034	1.006	32,226
1972	34,377	1.006	34,583
1973	na	-	38,322 est
1974	na	-	39,044 est

TABLE III-4

TOTAL RAIL FREIGHT OUTPUT BY MOVEMENT CATEGORIES

(000,000 ton-miles)

From (To) To (From)	Ontario Ontario	Ontario Quebec	Ontario Manitoba	Ontario U.S.A.	Manitoba Quebec
1957	5,210	3,892	9,733	3,550	1,833
1958	4,308	4,386	9,847	2,897	1,796
1959	5,178	3,342	9,815	3,082	1,416
1960	4,799	3,642	8,846	3,053	1,257
1961	4,549	4,037	8,769	2,735	1,595
1962	4,294	4,042	8,169	2,457	1,569
1963	4,383	4,933	9,413	3,040	1,453
1964	5,058	5,152	12,876	3,274	2,029
1965	5,778	5,347	11,384	3.395	1,873
1966	5,274	5,059	14,195	3,652	2,125
1967	5,468	4,844	11,980	3,437	2,777
1968	6,124	4,835	8,885	3,492	2,851
1969	4,692	5,192	9,658	3,401	2,931
1970	5,582	5,489	14,170	3,429	2,808
1971	5,344	5,502	14,857	3,288	3,043
1972	5,422	6,372	16,011	3,243	3,329

TABLE III-5

SPECIFIED CLASS AND GENERAL CLASS RAIL FREIGHT OUTPUT, ONTARIO

(000,000 ton-miles)

Year	Specified Class Commodity					General Class
	Grains	Coal	Iron Ore	Forest Products	Total	Total
1955	na	na	na	na	-	9,102 est
1956	na	na	na	na	-	10,602 est
1957	5,587	1,856	812	1,924	10,179	14,330
1958	6,284	1,379	768	1,888	10,319	13,147
1959	6,271	1,016	1,328	1,773	10,388	13,659
1960	5,879	851	1,211	1,575	9,516	12,254
1961	5,528	785	1,350	1,617	9,280	12,578
1962	5,116	765	1,348	1,694	8,923	12,276
1963	5,465	704	1,467	1,636	9,272	14,089
1964	7,411	933	1,688	1,923	11,955	16,576
1965	4,798	796	1,730	1,875	9,199	18,745
1966	7,313	809	1,544	1,872	11,538	18,919
1967	6,865	728	1,645	1,993	11,231	17,361
1968	3,293	549	1,779	1,971	7,592	18,647
1969	4,086	410	1,714	2,115	8,325	17,575
1970	6,174	1,451	1,831	1,978	11,434	20,201
1971	7,325	419	1,786	2,208	11,738	20,488
1972	7,235	229	2,101	2,626	12,191	22,392
1973	na	na	na	na	-	24,409 est
1974	na	na	na	na	-	25,411 est

(b) Transportation Output - Marine

Table III-6 summarizes General Class marine freight output in Ontario for the period 1955 to 1974. The procedure used to derive the series included the following steps:

(i) determination of typical mileages for marine freight movements between Ontario and extra provincial ports, between Ontario and United States Great Lakes ports, and between pairs of Ontario ports;

(ii) calculation of total output for all freight commodities as the sum of products of tonnages moved multiplied by appropriate mileage factors;

(iii) calculation of the sum of outputs for all Specified Class commodities;

(iv) subtraction of the sum of outputs for Specified Class commodities from the total output for all freight commodities.

A full explanation of sources and calculation procedures follows. Readers wishing to omit this portion of the report may turn to Section A.2.1 (c) Transportation Output - Highway.

Mileage factors used for calculations of marine freight output are shown in Table III-7. For each movement category a weighted average mileage was derived for each Specified Class commodity and for the "all commodities" category using 1973 SC data (III-4). The assumption was made that the weighted average mileage would have been constant in the preceeding years. For movements up and down the St. Lawrence, mileages

TABLE III-6

GENERAL CLASS MARINE FREIGHT OUTPUT, ONTARIO

(000,000 ton-miles)

Year		Year	
1955	4,286	1965	10,495
1956	5,826	1966	11,267
1957	5,549	1967	11,023
1958	5,387	1968	12,006
1959	5,872	1969	12,531
1960	6,263	1970	14,610
1961	7,319	1971	13,760
1962	7,304	1972	15,219
1963	7,827	1973	14,942
1964	10,155	1974	14,746

TABLE III-7

MILEAGE FACTORS USED TO CALCULATE MARINE FREIGHT OUTPUT

Movement	Mileage Factors				
	Grains	Coal	Iron Ore	Forest Products	All Commodities
Ontario to Ontario	699	500 est	618	-	582
Ontario down St. Lawrence	1,200	500 est	-	550 est	1,183
St. Lawrence to Ontario	-	503	374	-	400 est
Ontario to U.S. Great Lakes	632	-	533	500 est	498
U.S. Great Lakes to Ontario	583	233	865	-	483

were terminated at Montreal. A full explanation of this point may be found in Section A.4.2 (b).

Marine freight output for Specified Class commodities is shown in Table III-8. The series are based on CTC data which are similar to those used for rail movements, except the period covered is limited to 1963 to 1972 (III-2, 479-589). Thus, the annual output for each commodity is the sum of products of volumes moved multiplied by the appropriate mileage factors.

TABLE III-8

SPECIFIED CLASS MARINE FREIGHT OUTPUT, ONTARIO

(000,000 ton-miles)

Year	Grains	Coal	Iron Ore	Forest Products	Total
1963	12,063	2,978	7,469	209	22,719
1964	14,162	3,252	7,869	216	25,499
1965	13,193	3,619	7,176	201	24,189
1966	15,804	3,709	7,270	236	27,019
1967	10,780	3,769	6,116	213	20,878
1968	8,369	4,050	6,920	200	19,539
1969	7,540	3,774	6,480	272	18,066
1970	14,048	4,165	7,471	262	25,946
1971	15,873	4,062	6,388	240	26,563
1972	17,098	4,153	6,469	227	27,947

General Class marine freight output is shown in Table III-9 as the difference between total marine freight output and the sum of outputs for Specified Class commodities. Total marine freight output was calculated by combining separate SC sources for coastwise and foreign marine freight loadings

TABLE III-9

TOTAL, SPECIFIED CLASS AND GENERAL CLASS MARINE FREIGHT OUTPUT

(000,000 ton-miles)

Year	Total Output	Specified Class Output	Specified Class Percent of Total		General Class Output
1955	23,043	18,757	81.4	trend est	4,286
1956	29,423	23,597	80.2	trend est	5,826
1957	26,422	20,873	79.0	trend est	5,549
1958	24,377	18.990	77.9	trend est	5,387
1959	25,201	19,329	76.7	trend est	5,872
1960	25,564	19,301	75.5	trend est	6,263
1961	28,479	21,160	74.3	trend est	7,319
1962	27,253	19,949	73.2	trend est	7,304
1963	30,546	22,719	74.4		7,827
1964	35,654	25,499	71.5		10,155
1965	34,684	24,189	69.7		10,495
1966	38,286	27,019	70.6		11,267
1967	31,901	20,878	65.4		11,023
1968	31,545	19,539	61.9		12,006
1969	30,597	18,066	59.1		12,531
1970	40,556	25,946	64.0		14,610
1971	40,323	26,564	65.8		13,760
1972	43,166	27,947	64.7		15,219
1973	40,384	25,442	63.0	est	14,942
1974	37,810	23,064	61.0	est	14,746

TABLE III-10

TOTAL MARINE FREIGHT OUTPUT BY MOVEMENT CATEGORIES, ONTARIO

(000,000 ton-miles)

From: To:	Ontario Ontario	Ontario St. Lawrence	St. Lawrence Ontario	Ontario U.S. Great Lakes	U.S. Great Lakes Ontario
1955	5,645	2,774	1,635	3,087	9,902
1956	7,391	5,967	979	3,735	11,351
1957	6,402	4,743	734	3,386	11,157
1958	7,100	5,994	771	2,639	7,873
1959	6,460	5,875	1,256	3,834	7,776
1960	5,936	6,664	828	3,635	8,501
1961	6,693	9,304	932	3,436	8,114
1962	5,703	7,823	902	4,083	8,742
1963	5,994	10,177	931	3,784	9,660
1964	6,635	13,381	965	4,482	10,191
1965	6,053	12,623	1,452	3,834	10,722
1966	6,227	15,463	2,131	3,784	10,681
1967	5,413	10,730	2,363	3,784	9,611
1968	5,936	8,775	2,508	4,183	10,143
1969	6,751	7,826	1,942	3,984	10,094
1970	8,032	14,750	2,333	4,332	11,109
1971	7,333	16,547	2,320	3,884	10,239
1972	7,507	18,413	2,101	4,133	11,012
1973	7,449	15,587	2,092	4,582	10,674
1974	7,973	13,785	1,806	4,731	9,515

and unloadings in Ontario (III-5, III-6). For each movement category the volume figure was multiplied by the appropriate mileage factor to give the output series shown in Table III-10. Foreign movements up the St. Lawrence were excluded as it was assumed that there would be no dependence on Ontario fuels. Foreign movements down the St. Lawrence were calculated as the difference between total foreign movements and movements to United States Great Lakes ports. In order to extend the General Class marine output series back to 1955, a linear regression trend was calculated from the percentage of total output comprised by Specified class commodities in the 1963 to 1972 period. The trend was extended backwards through the years 1962 to 1955. Total Specified Class output for these years was estimated using the trend derived percentage and the calculated total marine output; General Class output was calculated as the difference between total output and estimated Specified Class output.

(c) Transportation Output - Highway

Table III-11 summarizes inter-city truck output in Ontario for the period 1955 to 1974. All truck output is considered to be General Class freight. There are no suitable, comprehensive sources of statistical data on trucking output available. Hence, indirect methods were required to provide a consistent and comprehensive basis for the series. The procedure used to derive the series included the following major steps:

(i) development of output estimates for 1973;

(ii) extension of the 1973 estimates to estimates for other years on the basis of truck registration statistics.

TABLE III-11

GENERAL CLASS TRUCK FREIGHT OUTPUT, ONTARIO

(000,000 ton-miles)

Year		Year	
1955	2,794	1965	7,061
1956	3,124	1966	7,654
1957	3,493	1967	8,297
1958	3,905	1968	8,994
1959	4,366	1969	9,749
1960	4,883	1970	10,560
1961	5,259	1971	11,912
1962	5,664	1972	13,437
1963	6,100	1973	15,162
1964	6,570	1974	17,102

A full explanation of sources and calculation procedures follows. Readers wishing to omit this portion of the report may turn to Section A.2.2 Explanatory Variables.

Trucking output estimates for 1973 are shown in Table III-12. Descriptions of procedures used to derive these estimates are numbered according to the following scheme:

	Intraprovincial	Interprovincial	International
For-hire*	(i)	(ii)	(iv)
Private*	(iii)	(iii)	(iv)

* *For-hire trucking includes common and contract carriers who move goods for compensation; private trucking involves operation of vehicles by businesses to carry their own goods, and does not involve compensation.*

(i) Intraprovincial for-hire trucking output has been measured as 4,511 million ton-miles in 1973, so no additional calculations are necessary (III-7).

TABLE III-12

1973 TRUCK FREIGHT OUTPUT, ONTARIO

Type	(000,000 ton-miles)
Intraprovincial for-hire	4,511
Intraprovincial private	1,579
Interprovincial for-hire	4,246
Interprovincial private	1,486
International	3,340
Total	15,162

(ii) Interprovincial for-hire trucking output in 1973 has also been measured (III-7). However, further manipulation is necessary to determine the Ontario portion of this traffic. A total of 6,535,042 tons were carried between Ontario and provinces to the east. Of this, 4,371,618 tons originated or terminated in nine specified cities (Toronto, Ottawa/Hull, St. Catherines, Hamilton, Kitchener, London, Windsor, Sudbury, Thunder Bay). For this traffic, the estimated mileage in each case from these locations to or from the Quebec boundary was multiplied by the appropriate tonnage to give an output figure. The remaining 2,163,424 tons with unspecified Ontario origins or destinations were assigned to various regions, mileages estimated, and output determined. Traffic between Ontario and

provinces to the west totaled 1,974,259 tons. Similar procedures were followed, using the Manitoba boundary as the basis of calculating distances travelled in Ontario.

(iii) Private truck traffic, both intraprovincial and interprovincial, presents a major challenge. The following estimates of the ratio of private to for-hire trucking provided a guide in estimating private trucking output:

- United States, 1970: 0.673 (ton-miles)(III-8)
- Ontario, 1956 to 1964: 0.336 to 0.768, mean = 0.500 (ton-miles)(III-9)
- Canada, 1955 to 1969: 0.248 to 0.477, mean = 0.359 (ton-miles)(III-10)
- Ontario, 1972: 0.371 (tons) (III-11)

Taking all of the above into consideration, a decision was made to estimate private trucking output, intraprovincial and interprovincial, at 0.35 of for-hire trucking output.

(iv) The Ontario portion of international trucking was estimated from foreign trade statistics. For-hire and private trucking are included in the basic statistics and no separate estimates are required. As quantity data provided in foreign trade statistics are unsuitable as a basis for ton-mile estimates, the first step was to estimate the value of truck-carried exports and imports moved into and out of Ontario. This was done according to the five major commodity categories:

- Animals
- Food, Feed, Beverages and Tobacco
- Crude Materials, Inedible*
- Fabricated Materials, Inedible
- End Products, Inedible

The value of exports from Ontario carried by truck in each category was aggregated directly from SC data (III-12). Values of goods imported from the United States into Ontario are also published by SC (III-13). No modal breakdown is available, so an estimate of the truck share of tonnages was made using modal patterns for the exports and earlier experience with this subject (III-14).

Tonnages for exports and imports were determined by using estimates of values per ton for each commodity category which were developed from export statistics (III-15). These are published using the same general commodity classification and permit values of exports by rail to be compared to tonnage delivered to U.S. rail connections.** The tonnages by commodity categories for imports and exports were then multiplied by the estimated mileage of the within Ontario distance to obtain total output estimates for the Ontario portion of international truck traffic.***

Apart from the major calculation effort that would be involved, there are other barriers to direct estimation of trucking output in other years. Good estimates of

* *"Metal in ores" was treated separately, its value per ton being much higher than for other commodities in this category.*

** *Traffic received from U.S. railways destined to U.S. points was subtracted.*

*** *The estimate is consistent with Ontario data reported in the federal Ministry of Transport International Truck Traffic Survey, August 1974.*

TABLE III-13

TRUCK REGISTRATIONS BY GVW CLASS, ONTARIO

GVW Class (tons)	1955	1960	1965	1970	1973*
less than 3	178,408	192,789	206,937	252,988	321,111
3 - 5	34,181	34,061	37,093	39,160	44,935
5 - 7	14,163	16,001	16,761	16,667	17,671
7 - 8	10,916	9,715	9,875	10,056	11,108
8 - 10	12,714	13,161	14,716	17,454	21,716
10 - 13	21,170	16,156	16,089	16,599	18,176
13 - 17	1,603	16,086	22,116	25,433	31,303
Over 17	2,178	6,282	12,517	24,337	38,877
Total	275,333	304,251	336,014	402,688	504,891

* *1973 extrapolated from 1965 to 1970 change in proportions of registrations in each GVW class (Table III-14).*

TABLE III-14

TRUCK OPERATING PARAMETERS BY GVW CLASS

GVW Class (tons)	Average Inter-City miles/year	Average Maximum Load (tons)	Average Load Factor*	Average Vehicle output/year** (ton-miles)
less than 3	5,300	0.7	0.05	186
3 - 5	4,800	1.5	0.15	1,080
5 - 7	5,000	3.5	0.30	5,250
7 - 8	5,500	4.5	0.40	9,900
8 - 10	6,000	5.2	0.50	15,600
10 - 13	10,500	6.5	0.55	37,538
13 - 17	24,000	9.5	0.55	125,400
over 17	30,879	15.0	0.55	254,752

* *equals actual load ÷ maximum load.*

** *equals average inter-city miles per year x average manimum load x average*

intraprovincial and interprovincial trucking output are only available for 1973 and foreign trade statistics became less and less suitable for the necessary calculations as the period of analysis is extended into the past. Lack of suitable data required use of a proxy measure to extend the 1973 output estimate to other years. The estimates for 1974 and for the years 1955 through 1972 were based on estimates of ton-mile output per registered truck in each of eight gross vehicle weight classes. These values were then applied to the truck fleet, by gross vehicle weight (GVW) class, in five years and the remaining output figures were estimated by interpolation.

Up to 1970, published truck registration data included registrations by GVW class (III-16). Registrations by GVW class for 1973 were estimated from the trend in size changes between 1965 and 1970.* Table III-13 shows numbers of trucks registered in each GVW class in selected years.

Estimates of output per vehicle for each GVW class were derived from a variety of U.S. sources (III-17 to III-22). This procedure involved estimating for each class the average number of inter-city vehicle-miles per year, the average maximum load, and the average load factor. Results are shown in Table III-14.

The truck operating parameters were applied to the vehicle registration data in Table III-13 to produce the inter-city truck output estimates shown in Table

* *Data compiled by R.L. Polk & Co. Ltd. for Environment Canada was used in a Progress Report. Subsequently, it was found that the data related to Census Metropolitan Areas only, and caused an exaggeration in the proportion of larger trucks.*

III-11*. Interpolation techniques were used to estimate the intermediate years. These estimates involved constant percentage increases over each period between the directly-estimated years.

* *Two modifications in Table III-14 were required to reflect changes in operating conditions. The average vehicle output per year value for the 10-13 ton class was increased to 50,000 in 1960 and 75,000 in 1955. Trucks in this class appear to have performed more inter-city miles in earlier years.*

2.2 Explanatory Variables

An equation describing the inter-city General Class freight sub-sector has been developed which examines the effect of five important explanatory factors. These are presented in Table III-15 .

(i) Production index proved a surprisingly difficult measure to develop satisfactorily. What was desired was an index which would demonstrate changes in physical output, such as that conveyed by the national index of real domestic product. The required information is, unfortunately, not available on a provincial basis, and as a result the index we have used is a measure of the value of shipments of goods manufactured in Ontario (OS Table 19.1) which is then deflated by the total industry selling price index.

(ii) Relative price index combines information on rail, marine, and truck modes, and deflates this aggregate series by the wholesale price index for Canada. The rail series was developed from the annual Waybill Analysis, based on a weighted (by ton-mile contributions) average of the average revenue per ton-mile and using information on commodity rates (for Eastern, competitive) and agreed charges (Eastern) for traffic originating in the Eastern region. Marine data was developed from the weighted annual revenues of Class I, II, and III inland carriers, (SC 54-205), and adjusted on the basis of ton-mile loading statistics. The basic truck data proved to be unavailable for either Ontario or Canada, and instead, since it

TABLE III-15

INDEPENDENT VARIABLES - GENERAL CLASS FREIGHT, TRANSPORTATION DEMAND

Year	(1) PRD	(2) TPI	(3) % URB	(4) $000,000 INF	(5) $000,000,000 GNP
1955	104	339	59.6	171	31.8
1956	113	315	60.0	214	34.5
1957	110	319	60.4	275	35.3
1958	105	323	60.8	320	36.1
1959	113	333	61.2	294	37.5
1960	116	343	61.6	298	38.6
1961	116	321	61.9	307	39.6
1962	127	318	62.3	274	42.3
1963	135	310	62.7	290	44.5
1964	149	296	63.1	301	47.5
1965	165	281	63.5	306	50.7
1966	172	261	64.6	363	54.2
1967	178	278	64.9	367	56.0
1968	190	267	65.3	375	59.3
1969	197	268	65.7	394	62.4
1970	193	263	65.8	383	64.0
1971	207	281	65.8	433	67.7
1972	229	264	65.8	400	71.7
1973	240	233	65.4	330	76.7
1974	216	205	65.0	333	78.8

(1) index of manufacturing activity.

(2) transportation price index.

(3) urbanization ratio.

(4) investment in infrastructure

(5) gross national product

was felt that relative changes in Canadian rates over the time period studied would closely resemble changes in the U.S. rates, a series collected annually by the I.C.C. (III-28) for U.S. carriers was utilized, and integrated with the other two series on the basis of estimated Ontario output data.

(iii) Urbanization ratio was utilized in the hope of providing a rough measure of changes in the spatial distribution of Ontario industry. The preferred variable would have measured changes over time in the relative importance of the value of total shipments of a designated geographical area (either the Toronto metropolitan area or a number of the most highly urbanized counties (see OS Table 19.3) compared to the corresponding output figure for all of Ontario. However, the required information is unavailable and thus, on the rationale that people follow employment opportunities, and employment moves with production levels, a measure of the changes in the percentage of the total population living in CMA's (OS Table 2.11), has been utilized.

(iv) Infrastructure investment draws on published Statistics Canada data to add the annual value of construction work performed on rail (track road bed, and signals), highway, and marine facilities in Ontario. This total was then deflated by the price index of industrial materials (OS Table 12.3).

(v) GNP is an annual series in constant 1961 dollars (SC 11-003).

2.3 Forecasting Model

(a) Introduction

For the General Class freight equations it was decided to implement two-stage estimation procedures rather than the one-stage techniques which had been used previously (Table III-16). Two-stage estimation is recommended whenever one of the independent variables (in this case PRD) is strongly correlated with one or more of the others. The two-stage procedures are then designed to first regress PRD on the other independent variables, and then to explicitly take this relationship into account when estimating the transport demand equation by regressing the newly estimated coefficients of PRD rather than the original series of the variable.

(b) Discussion of Results

The resultant equation looks very strong, with a high R^2 of 0.96 and all variables not only of the correct sign, but also (at the 5% level) highly significant. The correct interpretation of this equation raises certain difficulties; for example, the prior expectation of the correct sign for the variable describing population location (and thus, it is assumed, industrial location) over time was not entirely unambiguous. As the percentage of the total population which lives in CMA's increases, should we expect the demand for intercity General Class freight transport to decline (as more needs are met within the individual urban areas), or to rise (since with the population now more geographically polarized, additional shipments are required)? The model supports the first hypothesis, and hence predicts that an increase of 1 percent in the ratio will result in a

TABLE III-16

INITIAL REGRESSION MODEL: GENERAL CLASS FREIGHT, TRANSPORTATION DEMAND

General Form of the Transportation Demand Model:

GCF = f (PRD, TPI, URB, INF, GNP)

where

GCF = inter-city general class freight transportation demand (in ton-miles)
PRD = manufacturing activity index
TPI = transportation price index
URB = population distribution
INF = infrastructure investment
GNP = deflated gross national product

Basic Equations

$$PRD = c_0 + c_1 (TPI) + c_2 (URB) + c_3 (INF) + c_4 (GNP)$$

-427	0.089	7.3	-0.09	2.5
(-2.64)	(.73)	(2.64)	(-1.60)	(6.21)

$R^2 = 0.98$
F = 224

$$GCF = d_0 + d_1 (PRD) + d_2 (TPI) + d_3 (URB) + d_4 (INF)$$

180822	295	-77.5	-292	44.4
(2.66)**	(5.18)**	(-1.98)**	(-2.36)**	(2.11)**

$R^2 = 0.96$
F = 127

** *Significant at the .05 level.*

surprisingly large saving of nearly 300 million ton-miles. PRD is a strong variable, as would be expected, and price also yields a statistically significant series. Once again the INF series, despite the t-statistic of 2.11, could be interpreted to mean either that an additional one million dollars invested in infrastructure allows for an increase in shipments, or 44.4 million ton-miles results in an additional one million dollars worth of freight-related infrastructure.

3. Modal Shares

3.1 Historical Modal Shares

General Class freight output by mode is summarized in Table III-17, and modal shares are shown in a percent of total format in Table III-18. Data is based on modal output determinations described in preceeding sections. Table III-19 provides an index for General Class freight output by mode and in total using 1955 as a base year.

3.2 Explanatory Variables

The inter-city General Class freight sector has been disaggregated into two output equations, one which describes the historical output series for truck and rail modes, and another which describes the marine mode. In general, the two sub-sectors are not competitive, with each specializing in the transportation of different types of commodities. Extensive competition does, however, exist between truck and rail freight carriers; both one- and two-stage estimation techniques were utilized in attempts to develop separate modal share equations for these modes, but the results were unsatisfactory. We return to

TABLE III-17

GENERAL CLASS FREIGHT OUTPUT, ONTARIO

(000,000 ton-miles)

Year	Rail	Marine	Truck	Total
1955	9,102	4,286	2,794	16,182
1956	10,602	5,826	3,124	19,552
1957	14,330	5,549	3,493	23,372
1958	13,147	5,387	3,905	22,439
1959	13,659	5,872	4,366	23,897
1960	12,254	6,263	4,883	23,400
1961	12,578	7,319	5,259	25,156
1962	12,276	7,304	5,664	25,244
1963	14,089	7,827	6,100	28,016
1964	16,576	10,155	6,570	33,301
1965	18,745	10,495	7,061	36,301
1966	18,919	11,267	7,654	37,840
1967	17,361	11,023	8,297	36,681
1968	18,647	12,006	8,994	39,647
1969	17,575	12,531	9,749	39,855
1970	20,201	14,610	10,560	45,371
1971	20,488	13,760	11,912	46,160
1972	22,392	15,219	13,437	51,048
1973	24,909	14,942	15,162	55,013
1974	25,411	14,746	17,102	57,259

TABLE III-18

GENERAL CLASS FREIGHT MODAL SHARES, ONTARIO

(percent of total)

Year	Rail	Marine	Truck
1955	55.5	27.0	17.5
1956	54.2	29.8	16.0
1957	61.3	23.7	15.0
1958	58.6	24.0	17.4
1959	57.2	24.6	18.2
1960	52.4	26.8	20.8
1961	50.0	29.1	20.9
1962	48.6	28.9	22.5
1963	50.2	27.9	21.8
1964	49.8	30.5	19.7
1965	51.6	28.9	19.5
1966	50.0	29.8	20.2
1967	47.3	30.1	22.6
1968	47.0	30.3	22.7
1969	44.1	31.4	24.5
1970	44.5	32.2	23.3
1971	44.4	29.8	25.8
1972	43.9	29.8	26.3
1973	45.3	27.2	27.5
1974	44.4	25.8	29.8

TABLE III-19

INDEX OF GENERAL CLASS FREIGHT OUTPUT, ONTARIO

Year	Rail	Marine	Truck	All Modes
1955	100	100	100	100
1956	116	136	111	121
1957	157	129	125	144
1958	144	126	140	139
1959	150	137	156	148
1960	135	146	175	145
1961	138	171	188	155
1962	135	170	203	157
1963	155	183	218	173
1964	182	237	235	206
1965	206	245	253	224
1966	208	263	274	234
1967	191	257	297	227
1968	205	280	322	245
1969	193	292	349	246
1970	222	341	360	280
1971	225	321	426	285
1972	246	355	480	315
1973	274	349	543	340
1974	279	344	612	354

this difficulty following a discussion of the two selected equations.

The independent variables which were used in the development of the final equations are shown in Table III-20. These are the same variables used in the sectoral transportation demand equation, except that the series chosen for annual infrastructure investment and for price have been disaggregated to express the relative weighted (on the basis of ton-miles) modal contributions to the total. In addition, a new variable, VAL, expressing the average dollar value per ton-mile of freight shipped, has been developed from the weighted value of shipments of own manufactures (OS, Table 19.1) deflated by the annual industrial selling price index (SC 62-004). Its inclusion was originally based on the finding that an increase in the average value of shipments, relative to the general price level, would, for reasons related to both speed and safety (again, these potentially important service-quality variables were impossible to estimate directly), tend to favour the truck mode at the expense of the rail or marine modes. However, the results of the regression runs were consistently counter-intuitive and generally insignificant, so this variable was deleted.

3.3 Forecasting Model

(a) Introduction

The two models which were developed are shown in Table III-21.

TABLE III-20

INDEPENDENT VARIABLES - MODAL SHARES, GENERAL CLASS FREIGHT

Year	PRD	URB	TPI		INF		VAL
			rail & truck	marine	rail & truck	marine	($/T-M)
1955	104	59.6	93	42	141	18.6	.573
1956	113	60.0	87	42	156	21.5	.551
1957	110	60.4	91	40	192	29.4	.440
1958	105	60.8	95	48	233	46.6	.428
1959	113	61.2	101	45	245	46.4	.439
1960	116	61.6	108	46	259	40.1	.442
1961	116	61.9	104	40	271	26.3	.441
1962	127	62.3	104	49	268	20.6	.475
1963	135	62.7	99	49	269	15.6	.471
1964	149	63.1	97	45	268	14.1	.452
1965	165	63.5	91	48	279	17.9	.461
1966	172	64.6	85	44	293	27.9	.471
1967	178	64.9	95	44	320	31.7	.504
1968	190	65.3	93	47	338	31.6	.499
1969	197	65.7	94	43	330	27.5	.524
1970	193	65.8	94	37	350	26.5	.459
1971	207	65.8	100	34	378	24.1	.483
1972	229	65.8	94	32	350	24.1	.494
1973	240	65.4	81	28	292	18.6	.474
1974	216	65.0	72	23	262	16.5	.409

TABLE III-21

INITIAL REGRESSION MODEL: MODAL SHARES, GENERAL CLASS FREIGHT

General Form of the Modal Shares Model:

% TTM = f (PRD, TPI, INF, URB)

where

TTM = modal share of general class freight transportation demand (as a percent of total general class freight transportation ton-miles demand)

PRD = manufacturing activity index

TPI = transportation price index

INF = investment in infrastructure

URB = population distribution

Basic Equation:

$$\% \text{ TTM} = e_0 + e_1 (\text{PRD})_t + e_2 (\text{TPI})_t + e_3 (\text{INF})_t + e_4 (\text{URB})_t$$

	e_0	e_1	e_2	e_3	e_4
Truck & Rail :	192457	190	-369	87.6	-2970
	(1.67)	(3.92)**	(-2.26)**	(1.70)*	(-1.53)*

R^2 = 0.94

F = 60

DW = 0.99

	e_0	e_1	e_2	e_3	e_4
Marine:	-51922	29.5	-78.0		953
	(-4.59)**	(2.35)**	(-2.55)**		(4.32)**

R^2 = 0.98

F = 284

DW = 2.17

---

* Significant at the .10 level.

** Significant at the .05 level.

(b) Discussion of Results

Both equations successfully explain a significant percentage of the variation in the dependent variable ($R^2_{R,T} = 0.94$; $R^2_M = 0.98$) and in each equation all variables are significant at the 10 percent level. The strongly positive coefficient on URB marine is surprising: the results shown here suggest that the concentration of population in major urban centres decreases the demand for the rail and truck freight modes (as well as for General Class freight as a whole) but increases the demand for marine freight. Price appears to be a strong determinant of demand for both rail and truck, and for marine, while the level of PRD is also closely related to freight movements in both modes.

Truck and rail output are combined in a single output equation. Attempts to develop modal share equations for the individual modes did not meet with success. Service quality levels for rail and truck service are important factors in a shipper choice of mode and the suspicion is that, if a reliable service quality variable had been developed, a useful modal choice equation would have emerged. As it is, however, reliable time series data for any effective measure of inter-modal differences in service quality proved impossible to develop.

A recent study carried out by the Canadian Institute of Guided Ground Transport at Queen's University* does provide some information on the importance of service quality variables on modal choice. The part of the study of interest

* *Ronald E. Turner, Freight Model Selection in Canada, Report No. 75-4, 1975, pp. 46, 55-57.*

dealt with 13 commodity groups shipped between nine regions located along the Windsor-Quebec corridor. Multiple regression analysis was used to estimate the following modal split equation applicable to either rail or truck.

$$\begin{aligned}\text{Modal share} = {} & 0.59 + \underset{(5.25)}{0.21\ \text{weight}} - \underset{(5.5)}{0.22\ \text{price}} + \underset{(4.25)}{0.34\ \text{time}} \\ & - \underset{(1.43)}{0.10\ \text{time variation}} + \underset{(0.80)}{0.04\ \text{time unreliability}} \\ & - \underset{(7.89)}{0.71\ \text{rail dummy variable}} \qquad (R^2 = .44)\end{aligned}$$

Each variable, except the last, is in relative terms. Thus, a price for either rail or truck that is twice the level of the other mode affects the modal share by -.22 times 2, or -.44 (-44 percent). The other variables operated in a similar fashion. These results confirm that rail has major, but unspecified, service quality disadvantages (the rail dummy variable coefficient of -0.71) and that the mode which cannot offer consistent arrival times has a reduced modal share.

4. Energy Requirements

4.1 Rail Mode

(a) Historical Energy Use

Table III-22 summarizes General Class rail freight energy consumption in Ontario for the period 1955 to 1974. The assumption was made that there was no net gain or loss of energy outside the province by trains operating through Ontario. Ontario railway fuels moving from Ontario to Quebec, Manitoba, or the United States would have been offset by fuels moving into the province from these sources. Thus, railway fuel deliveries within Ontario's provincial boundaries could be considered to relate directly to railway output, as output was calculated on the basis of mileages which were terminated at the provincial boundaries. The procedure used to derive the energy consumption series involved the following steps:

(i) conversion of fuels delivered from natural units to an equivalent in energy content, and aggregation into a single energy consumption figure;

(ii) division of the energy consumption figure into freight and passenger components;

(iii) division of the freight energy consumption component into General Class and Specified Class sub-components.

A full explanation of sources and calculation procedures follows. Readers wishing to omit this portion of the report may turn to Section A. 4.1 (b) Forecasting Methodology.

TABLE III-22

GENERAL CLASS RAIL FREIGHT ENERGY CONSUMPTION, ONTARIO

(000,000,000 Btu's)

Year	Btu's	Btu's/ton-mile	Year	Btu's	Btu's/ton-mile
1955	6,372	700	1965	13,765	734
1956	7,421	700	1966	12,796	676
1957	8,542	596	1967	11,855	682
1958	8,596	653	1968	14,630	784
1959	9,871	722	1969	12,847	730
1960	9,578	782	1970	12,598	623
1961	9,477	753	1971	13,839	675
1962	9,994	814	1972	14,861	663
1963	11,098	788	1973	14,893	597
1964	11,543	696	1974	15,867	624

Consumption of various motive power fuels by railways is compiled on a provincial basis by SC(III-24). During the period under consideration the transition from coal-steam to diesel-electric power was completed, with no significant coal consumption after 1959. Throughout the period the principal fuel type was diesel, however,there was also consumption of heavy and light fuel oils and kerosene during the earlier years. All fuels were converted from natural units to Btu energy equivalent as a first step in determining freight energy consumption.

No provincially aggregated data is available to permit a split of railway energy consumption between freight and passenger service. Therefore, it was necessary to assume that the Ontario split would have been the same as the national split. National data were used to calculate the ratio of freight service energy

consumption (all switching fuel assigned to freight) to freight plus passenger energy consumption (III-24). Total railway energy consumption, the freight to passenger energy split, and freight and passenger energy consumption are listed in Table III-23.

TABLE III-23

RAILWAY FUEL CONSUMPTION, ONTARIO

(000,000,000 Btu's)

Year	Total Energy	Freight / Freight & Passenger	Freight Consumption	Passenger Consumption	General Class / Total Freight
1955	14,351	0.779	11,179	3,172	0.570
1956	16,522	0.788	13,019	3,503	0.570
1957	19,137	0.763	14,602	4,535	0.585
1958	20,659	0.743	15,350	5,309	0.560
1959	22,988	0.756	17,379	5,609	0.568
1960	22,453	0.759	17,042	5,411	0.562
1961	21,323	0.773	16,483	4,840	0.575
1962	22,244	0.776	17,261	4,983	0.579
1963	23,296	0.790	18,404	4,892	0.603
1964	24,929	0.797	19,868	5,061	0.581
1965	25,643	0.800	20,514	5,129	0.671
1966	25,068	0.822	20,606	4,462	0.621
1967	25,266	0.773	19,531	5,735	0.607
1968	24,972	0.824	20,577	4,395	0.711
1969	22,659	0.835	18,920	3,739	0.679
1970	22,898	0.861	19,715	3,183	0.639
1971	24,897	0.874	21,760	3,137	0.636
1972	26,162	0.878	22,970	3,192	0.647
1973	26,246	0.873	22,913	3,333	0.650
1974	28,484	0.857	24,411	4,073	0.650

The final step in determining General Class freight energy consumption was splitting total freight consumption into General Class and Specified Class sub-components. It was assumed that energy intensiveness of the two service types was equal. In fact, this may not be the precise case; however, there is no statistical basis for other assumptions. It might have been assumed that Specified Class service would be more energy efficient than General Class service. The most advanced technology could be in use, the totally repetitive nature of service would induce efficiency in scheduling mainline right-of-way, minimizing switching, and so on. This assumption was avoided, as in the Ontario context there is no evidence of advanced unit-train technology. Further, the induced efficiency in operations management is offset by the fact that Specified Class load factor would seldom exceed 50 percent. Either the cars are single purpose (ore cars, some grain cars), or there is little demand for service in the opposite direction to the Specified Class flow. At the present time, there appears to be no basis for differentiating energy intensiveness of different freight service components. Freight energy consumption has therefore been split between General Class and Specified Class in direct proportion to the relative outputs of the two freight sub-components. Table III-23 indicates the ratio of General Class output to total output on the basis of data in Tables III-3 and III-5. Table III-22 was calculated by multiplying these ratios by total freight energy consumption figures.

Examination of the energy intensiveness column in Table III-22 indicates a trend towards greater efficiency in rail operations. There are some notable fluctuations in the series. During the mid to late 1950's, efficiency appears high relative to the early 1960's. This is believed to be due to imbalance between fuels moving into and out of the province. It is suggested

that the coal powered trains entering the province brought in more motive fuel coal than coal powered trains leaving the province. Year-to-year fluctuations in the period from 1960 to 1974 cannot be adequately explained. There is some degree of correlation between high output years and high energy efficiency years, which suggests a threshold energy consumption level to support the rail system. Other causes for fluctuations could include imbalance between fuels moving into and out of the province, errors in statistical data, or lack of constant relationships in any of the areas in which assumptions were required. A linear regression trend was calculated for energy intensiveness during the period 1960 to 1974. It was found:

$$EI = 24{,}368 - 12.03\ Y$$
$$r = -0.797$$

where EI is the energy intensiveness in Btu's per ton-mile, and Y is the year. The equation may be considered to give a more meaningful energy intensiveness factor than the observed factor for any particular year. Thus, for a 1974 base year an equation calculated factor of 621 Btu's per ton-mile would be used rather than the observed 624 Btu's per ton-mile. During 1974, all Ontario railway fuel was diesel oil.

(b) Forecasting Methodology

The procedure for forecasting energy requirements for General Class rail freight includes the following steps:

(i) forecasting General Class rail and truck freight output for the period under consideration using the regression equation detailed in Section A.2.3 Forecasting Model; and projected values of independent explanatory variables.

(ii) forecasting the rail share of forecast rail truck output on the basis of assumed modal split;

(iii) Calculation of an energy intensiveness factor for the rail mode using the equation detailed in Section A.4.1(a) Historical Energy Use;

(iv) preparation of a base case energy requirement forecast on the basis of the forecast rail share of General Class freight and calculated energy intensiveness factor;

(v) examination of the sensitivity of energy requirements to potential changes which would influence these requirements.

(c) Energy Sensitivity

While technological innovations for the rail mode have been given considerable attention in recent years, it would appear that the focus of this attention has not generally been directed towards reducing or changing energy intensiveness. Rather, efforts have been directed toward objectives such as improving tractive efficiency, lowering centres of gravity, reducing derailment potential, reducing rail loading, and improving speed and efficiency in loading and unloading operations. Changes in energy intensiveness may result if new technology is introduced; however, they may either increase or reduce energy requirements. A general trend towards

reduced energy intensiveness is indicated by the energy intensiveness equation for rail freight. The reduction appears to result from a combination of improved technology and improved operations management.

Railway electrification offers a significant opportunity for energy substitution, and may, depending on the type of generation, bring a reduction of overall energy intensiveness. For further discussion, reference should be made to Chapter II, Section A. 4.4 (c).

4.2 Marine Mode

(a) Historical Energy Use

Table III-24 summarizes General Class marine freight energy consumption and energy intensiveness in Ontario for the period 1955 to 1974. The procedure used to derive the energy consumption series involved the following steps:

(i) conversion of fuels consumed from natural units to an equivalent in energy content;

(ii) division of energy consumption into General Class and Specified Class components.

A full explanation of sources and calculation procedures follows. Readers wishing to omit this portion of the report may turn to Section A. 4.2(b) Forecasting Methodology.

Disposition of various marine fuels is compiled on a provincial basis by SC(III-25, III-26). Relevant data for Ontario was converted from natural units to Btu energy equivalent and aggregated for a total energy consumption series for General Class and Specified Class marine freight. It was assumed that energy intensiveness of the two service categories was equivalent. Thus, General Class energy consumption was calculated as the product of total energy consumption multiplied by the ratio of General Class to total marine freight output.

Determination of marine freight energy intensiveness as shown in Table III-24 presented a major problem. For a meaningful relationship it is essential that energy consumption is related to the output which is dependent upon it. With the flexibility in fueling which is available to ships, it

TABLE III-24

MARINE FREIGHT ENERGY CONSUMPTION, ONTARIO

(000,000,000 Btu's)

Year	Total Btu's	General Class / Total Freight	General Class Btu's	Btu's/ton-mile
1955	15,970	0.186	2,970	693
1956	19,669	0.198	3,894	668
1957	17,493	0.210	3,674	662
1958	15,527	0.221	3,431	636
1959	15,588	0.233	3,632	618
1960	14,828	0.245	3,633	580
1961	15,026	0.257	3,862	527
1962	15,165	0.268	4,064	556
1963	15,008	0.256	3,842	490
1964	17,905	0.285	5,103	502
1965	25,417	0.303	7,701	733
1966	26,196	0.294	7,702	683
1967	20,165	0.346	6,977	632
1968	19,999	0.381	7,620	634
1969	19,727	0.409	8,068	643
1970	22,161	0.360	7,978	546
1971	19,778	0.342	6,764	491
1972	18,801	0.353	6,637	436
1973	25,542	0.370	9,451	632 (500 trend est)
1974	25,336	0.390	9,881	670 (490 trend est)

becomes very difficult to relate a particular set of fuel delivery data to an appropriate set of transportation data. In the Ontario-Great Lakes situation, the following variations in fueling may occur:

(i) fuel related to Ontario loadings or unloadings may be purchased from facilities in Ontario, along the St. Lawrence, or in the United States (Great Lakes ports);

(ii) United States vessels moving between pairs of non-Ontario ports may purchase fuel from facilities in Ontario.

It is impossible to avoid making a series of assumptions prior to calculating marine transportation output dependent upon fuel sales from Ontario facilities.

To gain a better understanding of marine fueling patterns on the Great Lakes, discussions were held with a number of consumers and suppliers of marine fuels (III-27). While the desired level of clarification could not be obtained,the following points may be considered a concensus of opinions:

(i) with the exception of 1973 and 1974 when supply shortages developed, it has been desirable to obtain as much fuel as possible from facilities along the St. Lawrence,as the cost is generally lower;

(ii) for the grain eastward to St. Lawrence ports, iron ore westward to Ontario ports circuit, the desirability of fueling in the St. Lawrence is reduced by draft limitations of the Seaway and

loss of iron ore cargo capacity, and operators bear the higher cost of Ontario fuels;

(iii) United States ships frequently obtain fuels from Ontario facilities, as they are conveniently located;

(iv) with some exceptions, Canadian Ships tend not to fuel from United States facilities.

Taking the above points into consideration, assumptions were made prior to calculations of marine output as described in Section A.2.1 (b):

(i) mileages for movements between Ontario and St. Lawrence ports were terminated at Montreal. Movements east of Montreal to ports such as Baie Comeau, Port Cartier, Quebec and Sorel, and from ports such as Sept Iles, and Pointe Noire were not considered to be dependent on Ontario fuels. Movements west of Montreal en route to or from these ports were considered wholly dependent on Ontario fuels;

(ii) all movements between Ontario and United States Great Lakes ports were considered wholly dependent on Ontario fuels. Fuels for these movements which were, in fact, delivered from facilities in the United States were considered to be offset by fuel purchases from Ontario facilities for movements between non-Ontario ports;

(iii) all movements between pairs of Ontario ports were considered wholly dependent on Ontario fuel deliveries.

Inasmuch as fueling patterns changed in 1973 and 1974, the relationship between output and energy consumption is clearly in error for these years. Energy intensiveness factors for these years were estimated on a linear regression trend basis and are shown in parenthesis in Table III-24. Fueling is considered to have returned to the pre-1973 pattern, so it is unncessary to change mileage factors in marine output calculations for base case energy forecasting.

Examination of the energy intensiveness column of Table III-24 indicates a rather uncertain understanding of the relationship between marine output and energy consumption. The assumptions concerning dependence of movements on Ontario fuels may be considered suspect; however, the fact that sudden fluctuations in energy intensiveness do not correspond with major changes in output for various movement categories (Table III-10) seems to indicate that this is not a full explanation. There is the possibility of abberations in statistical data. In particular, energy sales in 1965, 1966, and 1967 would appear to be incorrect in the SC data which was used. While reference to detailed records of petroleum companies was not obtained, neither marine fuel sales specialists nor shipping operators could recall any factor to explain the apparent 42 percent jump in fuel sales between 1964 and 1965 (III-27). Discussion with SC led to the conclusion that reporting changes could have resulted in major inconsistency in the series, but there is little possibility of documenting these changes ten years after the data was compiled (III-28).

Linear regression trends were calculated for energy intensiveness during the period 1955 to 1972, the first using every year's factor, and the second omitting factors for 1965, 1966 and 1967. For the first calculation it was found:

$$EI = 14{,}018 - 6.84\ Y$$
$$r = -0.437$$

and for the second:

$$EI = 17{,}605 - 8.67\ Y$$
$$r = -0.634$$

where EI is the energy intensiveness in Btu's per ton-mile and Y is the year. Either equation could be used to calculate an energy intensiveness factor for a base year. For 1974 the first equation gives a factor of 516 Btu's per ton-mile and the second equation gives a factor of 490 Btu's per ton-mile. The latter factor is considered to be the better for base case forecasting.

As a check on energy intensiveness results, questionnaires were sent to nine Great Lakes shipping companies with varying levels and types of operation. Data was requested on output and energy consumption for each ship in each company's fleet. Only two companies were able to provide useful time series data: Upper Lakes Shipping Limited, and Scott Misener Steamships Limited, and their responses were considered to be of exceptionally high quality. For the combined fleets of the two companies a 1974 energy intensiveness factor was calculated as 335 Btu's per ton-mile with a rate of decline of approximately 14.5 Btu's per ton-mile per year. For the combined steamer fleets (internal combustion motor vessels excluded) of the two companies, the 1974 energy intensiveness factor was calculated as 372 Btu's per ton-mile with a rate of decline of approximately 13.6 Btu's per ton-mile per year.

The two types of energy intensiveness factors are considered to compare favourably. There are two reasons for the company energy factors being lower than the total energy to total output ratio factors:

(i) company energy factors fail to recognize a marine infrastructure which includes support and maintenance vessels, and other marine operators such as tugs and barges, car ferries, etc. In the total energy to total output ratio, these energy consumers must be assumed to maintain a constant relationship to marine output, as they can not be documented from statistical sources;

(ii) the larger Great Lakes operators such as Upper Lakes Shipping Limited, and Scott Misener Steamships Limited, would be expected to be leaders in energy efficiency. The larger companies led in the transition from coal fired steam to oil fired steam, and appear to be leading again in the transition from oil fired steam to internal combustion diesel - heavy oil mixtures. They also operate the larger (Canadian) lake ships. It may be assumed that some of the older, less efficient lake ships have passed from the large operators to the average and smaller operators.*

Further reference will be made to company energy factors in the subsequent sensitivity section. On the basis of all marine energy data examined, it is considered 490 Btu's per ton-mile is an appropriate energy intensiveness factor for use in base case forecasting.

* *A great deal of background information on Great Lakes shipping, fleets, facilities, etc. may be found in one of the annual Greenwood's Guide to Great Lakes Shipping volumes. Current copies are available from Freshwater Press, Inc. 258 The Arcade, Cleveland, Ohio. 44114, U.S.A.*

A number of fuel types are used in Great Lakes marine operations. During recent years the breakdown between fuel types in terms of energy content was as follows:

	1971	1972	1973	1974
Heavy Fuel Oil	68.6%	69.7%	68.6%	72.7%
Light Fuel Oil	0.4%	0.4%	0.2%	1.3%
Kerosene	0.8%	0.1%	0.1%	0.2%
Diesel Oil	10.8%	13.7%	18.2%	16.6%
Coal	19.4%	16.1%	12.9%	9.2%

An appropriate breakdown for base case forecasting is considered to be 74 percent oils (including approximately one percent light fuel oil, 0.1 percent kerosene, and the remainder heavy fuel oil), 17 percent diesel oil, and 9 percent coal.

(b) Forecasting Methodology

The procedure for forecasting energy requirements for General Class marine freight includes the following steps:

(i) forecasting General Class freight output: Section A. 4.1 (b);

(ii) calculation of an energy intensiveness factor for the marine mode using the equation detailed in Section A. 4.2 (a);

(iii) preparation of a base case energy requirement forecast on the basis of the forecast marine share of General Class freight, and calculated energy intensiveness factor;

(iv) examination of the sensitivity of energy requirements to potential changes which would influence these requirements.

(c) Energy Sensitivity

Fuel is a major cost item in shipping operations, and considerable attention is given to maintaining performance of existing ships and improving performance of new ships. Changes and modification which may lead to improvement in energy intensiveness factors are discussed below:

(i) The transition from coal and petroleum fired steamers to internal combustion diesel - heavy oil mixture motor vessels is bringing a significant reduction in energy intensiveness. Company data obtained through the questionnaire discussed in the previous section indicates present-day heavy fuel oil fired steamers consume between 300 and 450 Btu's per ton-mile, and diesel-heavy oil mixture powered motor vessels consume between 200 and 250 Btu's per ton-mile. While coal fired steamers are only found in the American fleet at this time, the historical data supplied by respondents to the questionnaire indicate energy intensiveness would be in the 450 to 650 Btu's per ton-mile range. For sensitivity tests, appropriate 1974 energy intensiveness factors are considered to be 400 Btu's per ton-mile for heavy fuel oil fired steamers, 225 Btu's per ton-mile for diesel-heavy oil mixture powered motor vessels, and 525 Btu's per ton-mile for coal fired steamers.

(ii) Introduction of ships with greater capacity should reduce energy intensiveness factors.

(iii) Improved maintenance procedures can contribute to fuel economy. Most larger operators maintain cleanliness of boiler tubes already; however, smaller operators may be operating steamers with energy wasting residues on both the inside and outside of these tubes.

(iv) Various additives and fuel preparation attachments are claimed to improve fuel performance. It is questionable whether a significant improvement is achieved in a well maintained ship with a clean boiler or engine.

Continuation of the annual reduction in the energy intensiveness factor for Great Lakes shipping operations may be anticipated from a natural evolution of the system in terms of factors such as those above. The evolution may be complemented by changes in the nature of operations. An example would be introduction of far larger ships in the Canadian fleet with an operating area confined to the Upper Lakes. Study of United States operators with large vessels on the Upper Lakes would allow assessment of the significance of these ships to overall energy consumption patterns.

4.3 Highway Mode

(2) Historical Energy Use

Table II-25 summarizes inter-city truck freight energy consumption in an energy intensiveness by gross vehicle weight (GVW) format (III-19, III-21). A full explanation of the procedure used to derive the series follows. Readers wishing to omit this portion of the report may turn to Section A. 4.3 (b) Forecasting Methodology.

The methodology for determining energy use by trucks in inter-city freight transportation is similar to that used for inter-city automobile transportation. The similarity involves the procedure of disaggregating the vehicle fleet in the course of studying its use of energy. In the case of automobiles the disaggregation is by model year; for trucks the disaggregation is by GVW class.

TABLE III-25

ENERGY CONSUMPTION BY GVW CLASS

GVW Class (tons)	Energy Consumption (gallons/mile)	(Btu's/mile)
less than 3	0.067	9,996
3 - 5	0.077	11,488
5 - 7	0.091	13,577
7 - 8	0.100	14,920
8 - 10	0.125	18,650
10 - 13	0.143	21,336
13 - 17	0.167	24,916
over 17	0.200	30,993

The proportion of the truck fleet in each of the eight GVW classes may be estimated in one of two ways.

(i) Extrapolation

The GVW class proportions shown in Table III-26 may be used to develop rates of change over time (III-16). Annual changes for the periods 1960 to 1970 and 1965 to 1970 are shown in Table III-27.

TABLE III-26

SIZE DISTRIBUTION OF TRUCK FLEET, ONTARIO

(percent)

GVW Class (tons)	1955	1960	1965	1970	1973*
less than 3	64.8	63.4	61.6	62.8	63.6
3 - 5	12.4	11.2	11.0	9.7	8.9
5 - 7	5.1	5.3	5.0	4.1	3.5
7 - 8	4.0	3.2	2.9	2.5	2.2
8 - 10	4.6	4.3	4.4	4.3	4.3
10 - 13	7.7	5.3	4.8	4.1	3.6
13 - 17	0.6	5.3	6.6	6.3	6.2
over 17	0.8	2.1	3.7	6.1	7.7

* *1973 extrapolated from 1965 to 1970 changes; columns may not total 100.0 because of rounding.*

TABLE III-27

CHANGES IN GVW CLASS PROPORTIONS

GVW Class (tons)	1960 - 1970	1965 - 1970
less than 3	- 0.06	+ 0.24
3 - 5	- 0.14	- 0.26
5 - 7	- 0.12	- 0.18
7 - 8	- 0.07	- 0.08
8 - 10	-	- 0.02
10 - 13	- 0.12	- 0.14
13 - 17	+ 0.13	- 0.06
over 17	+ 0.40	+ 0.48

(ii) Subjective Selection

It would not be unreasonable to augment or even replace the extrapolation technique with GVW class shares based on study of probable changes in truck technology and licencing regulations.

The value of ton-miles per vehicle averaged for the whole truck fleet in the year for which projections are being made is determined. This value is the weighted average, using class shares selected from the procedure above, of the average vehicle output per year factors shown in Table III-14. It is used to convert the inter-city truck freight output forecast into a forecast of total truck fleet size. From this, the total vehicle-miles for each GVW class may be determined. The vehicle-mile forecast is used to determine an energy use forecast based on energy consumption factors shown in Table III-25. While data to support a split between diesel oil and gasoline is lacking, it is estimated that a reasonable split is approximately 30 percent diesel oil and 70 percent gasoline.

(b) Forecasting Methodology

The procedure for forecasting energy requirements for General Class highway freight includes the following steps:

(i) forecasting the General Class rail and truck freight output for the period under consideration using the regression equation detailed in Section A.2.3. Forecasting Model and projected values of independent variables;

(ii) forecasting the truck share of forecast rail and truck output on the basis of assumed modal split;

(iii) forecasting total truck fleet size, GVW class proportions and vehicle-miles, and energy requirements;

(iv) examination of the sensitivity of energy requirements to potential changes in highway transportation technology.

(c) Energy Sensitivity

A variety of factors could affect energy requirements for inter-city trucking. Less research on energy use has been carried out for inter-city truck transport than for most other modes, so potential modifications can only be discussed on a subjective basis. A number of changes and modifications are discussed below.

(i) One change is the shift to larger trucks. From 1955 to 1974 the average truck size in Ontario increased from 3.9 tons to 5.6 tons. This has caused an increase in the ratio of ton-miles to vehicle-miles and, if this trend continues in the future, the ratio could increase from its present ratio of 3.19 by about 0.06 per year. Increases in maximum permissible G.V.W. also contribute to improving the ton-mile per vehicle-mile ratio (II-29).

(ii) The ratio of cargo weight capacity to gross vehicle weight increases with truck size and can be improved over time with improved structural materials and design. This also contributes to higher productivity.

(iii) Steady-speed operation on level, straight highways increases vehicle-miles per gallon. Highway investment to secure such operating characteristics can contribute significantly to improving fuel utilization (III-30).

(iv) Operating factors affect the measure of overall productivity in inter-city trucking.

These include the average density of freight*, the incidence of empty backhauls and, related to both, the use of specialized trucks. Specialized trucks may alleviate the density problem, but they often aggravate the empty backhaul problem.

(v) Improved maintenance procedures and driving techniques could increase the vehicle-miles that can be produced from a given quantity of fuel.

(vi) A variety of technological improvements in trucks could improve fuel utilization. Those that are mentioned frequently include the following (III-31).

- Advances in engine technology would include new, small diesel engines, more efficient large diesel engines and, possibly, the gas turbine engine. The latter has many advantages, but a major effect in reducing fuel consumption is not one of them.

- Improvements in truck transmissions, cooling systems, axles, and tires would make fuel use more efficient.

- The reduction of truck frontal area and streamlining would improve the aerodynamic qualities of large highway freight vehicles. While testing programs have generally lacked a

* *Trailers are often filled to capacity before legal GVW is reached.*

> desirable level of scientific discipline, current trucking periodicals indicate tractor mounted air deflectors result in energy savings of 10 percent or more when used in semi-trailer operations. The maximum potential in fuel economy by 1980 is estimated as 18 percent by the U.S. Transportation Systems Centre; however, detailed estimates of fuel savings associated with each improvement are not stated (III-32, 94-95).

Major shifts in the operating parameters of the inter-city trucking industry might save fuel but increase other energy or capital requirements. The most obvious case of this is new highway investment made to save truck fuel. Comprehensive study of investment and energy consequences would be required.

There is little discussion of intermodal piggyback transportation in this section. While the energy savings of major truck-to-piggyback shifts have been characterized as rather minor (III-33, III-34), many of the technological developments discussed in this section would also have a "rather minor" impact. The need for reductions in Btu per ton-mile ratios suggests that greatly increased use of piggyback is a technological innovation worth pursuing.

B. INTER-CITY SPECIFIED CLASS FREIGHT

1. Introduction

The inter-city Specified Class freight sector includes six commodities or commodity groups: grains, coal, iron ore, forest products, natural gas, and oil.* While total energy requirements are related to total transportation output, data allow presentation of data in disaggregated form by commodity, by mode and by movement category (regional origin-destination).

Forecasts for Specified Class freight transportation demand are derived on a commodity by commodity, and, as necessary, on a movement category by movement category basis. Forecasts accept a calculated output in an historical base year and are built upon the basis of industrial forecasts for industries directly related to each specific commodity or on forecasts of future demand for each commodity. No attempt is made to relate historical or future output or modal shares to independent socio-economic indicators. Such a relationship would be misleading for at least three reasons:

(i) transportation demand may result from forces external to the area for which meaningful indicators can be established; for example, foreign demand for Canadian grains will be a major influence on the volume of grains moving through Ontario;

* *"grains" includes SC classifications of wheat and all other grains; coal includes metallurgical and steam coal; iron ore includes iron ore and concentrates; forest products includes SC classifications of lumber, wood pulp and newsprint (excludes pulp wood); oil is primarily crude oil but includes other liquid petroleum products moved by pipeline.*

(ii) transportation demand may change suddenly, as for example, in the case of exhaustion of an iron ore reserve or opening of a coal fired thermal electric generating facility;

(iii) modal shares will be determined, to some extent, by arbitrary decisions; for example coal might never move by ship from Thunder Bay to Lake Ontario if it was decided to build a slurry pipeline from the mine site to the consumption sites.

Future energy requirements are a function of modal demand and energy intensiveness. For base case forecasting, recent energy intensiveness factors are used, aggregated for each mode. Subsequent to base case forecasting, the forecaster may test the sensitivity of energy requirements to changes in anticipated future commodity demands, modal shares, and transportation technology.

2. Transportation Demand

2.1 Historical Transportation Output and Modal Shares

(a) Transportation Output - Grains

Table III-29 summarizes transportation output and modal shares for gains for the period 1963 to 1972. The output data was calculated in the course of preparation of General Class rail and marine freight output data. Reference should be made to Section A. 2.1 (a) and A. 2.1 (b) for a description of the procedure which was followed. Table III-29 is based upon Tables III-5 and III-8 for rail and marine modes respectively. Output volumes for each movement category are listed in Tables III-30 and III-31. This disaggregated data may prove to be useful background material in future work related to forecasting transportation energy requirements.

(b) Transportation Output - Coal

Table III-32 summarizes transportation output and modal shares for coal for the period 1963 to 1972. Output volumes for each movement category are listed in Tables III-33 and III-34. Structure of this section parallels the preceding section on grains.

(c) Transportation Output - Iron Ore

Table III-35 summarizes transporation output and modal shares for iron ore for the period 1963 to 1972. Output volumes for each movement category are listed in Tables III-36 and III-37. Structure of this section parallels the preceding section on grains.

TABLE III-29

FREIGHT OUTPUT AND MODAL SHARES FOR GRAINS, ONTARIO

(000,000 ton-miles)

	Output			Percentage Share	
Year	Rail	Marine	Total	Rail	Marine
1963	5,465	12,063	17,528	31	69
1964	7,411	14,162	21,573	34	66
1965	4,798	13,193	17,991	27	73
1966	7,313	15,804	23,117	32	68
1967	6,865	10,780	17,645	39	61
1968	3,293	8,369	11,662	28	72
1969	4,086	7,540	11,625	35	65
1970	6,174	14,048	20,222	31	69
1971	7,325	15,873	23,198	32	68
1972	7,235	17,098	24,333	30	70

TABLE III-30

RAIL FREIGHT OUTPUT FOR GRAINS BY MOVEMENT CATEGORIES

(000,000 ton-miles)

From (To) To (From)	Manitoba Lakehead	Manitoba Ontario	Ontario Quebec	Ontario U.S.A.	Ontario Ontario	Manitoba Quebec
1963	3,097	1,438	600	152	178	-
1964	4,048	2,563	413	181	199	7
1965	3,687	142	662	146	161	-
1966	4,488	2,144	403	128	150	-
1967	3,141	3,221	182	96	225	-
1968	2,263	382	386	81	181	-
1969	2,272	1,150	390	88	186	-
1970	4,016	1,362	486	122	188	-
1971	4,299	2,312	408	126	180	-
1972	4,989	1,238	721	128	159	-

TABLE III-31

MARINE FREIGHT OUTPUT FOR GRAINS BY MOVEMENT CATEGORIES

(000,000 ton-miles)

From (To) To (From)	Ontario St. Lawrence	Ontario U.S. Great Lakes	Ontario Ontario
1963	9,146	339	2,578
1964	11,123	298	2,741
1965	10,481	273	2,439
1966	12,976	311	2,517
1967	8,439	310	2,031
1968	6,734	273	1,362
1969	5,415	237	1,888
1970	11,744	245	2,059
1971	13,972	154	1,747
1972	14,642	397	2,059

TABLE III-32

FREIGHT OUTPUT AND MODAL SHARES FOR COAL, ONTARIO

(000,000 ton-miles)

	Output			Percentage Share	
Year	Rail	Marine	Total	Rail	Marine
1963	704	2,978	3,682	19	81
1964	933	3,252	4,185	22	78
1965	796	3,619	4,415	18	82
1966	809	3,709	4,518	18	82
1967	728	3,769	4,497	16	84
1968	549	4,050	4,599	12	88
1969	410	3,774	4,184	10	90
1970	1,451	4,165	5,616	26	74
1971	419	4,062	4,481	9	91
1972	229	4,153	4,374	5	95

TABLE III-33

RAIL FREIGHT OUTPUT FOR COAL BY MOVEMENT CATEGORIES

(000,000 ton-miles)

From (To) To (From)	Manitoba Ontario	Quebec Ontario	U.S.A. Ontario	Ontario Ontario
1963	247	225	137	95
1964	416	297	111	109
1965	434	139	105	118
1966	442	101	162	104
1967	408	104	135	81
1968	305	106	72	66
1969	201	40	129	40
1970	1,181	74	130	64
1971	231	71	75	42
1972	123	17	26	63

TABLE III-34

MARINE FREIGHT OUTPUT FOR COAL BY MOVEMENT CATEGORIES

(000,000 ton-miles)

From (To) To (From)	St. Lawrence Ontario	U.S. Great Lakes Ontario	Ontario Ontario
1963	-	2,978	-
1964	196	3,056	-
1965	244	3,367	8
1966	368	3,339	2
1967	398	3,371	-
1968	389	3,661	-
1969	123	3,648	3
1970	14	4,147	4
1971	3	4,047	12
1972	1	4,152	-

TABLE III-35

FREIGHT OUTPUT AND MODAL SHARES FOR IRON ORE, ONTARIO

(000,000 ton-miles)

	Output			Percentage Share	
Year	Rail	Marine	Total	Rail	Marine
1963	1,467	7,469	8,936	16	84
1964	1,688	7,869	9,557	18	82
1965	1,730	7,176	8,906	19	81
1966	1,544	7,270	8,714	18	82
1967	1,645	6,116	7,761	21	79
1968	1,779	6,920	8,699	21	79
1969	1,714	6,480	8,194	21	79
1970	1,831	7,471	9,302	20	80
1971	1,786	6,388	8,174	22	78
1972	2,101	6,469	8,570	25	75

TABLE III- 36

RAIL FREIGHT OUTPUT FOR IRON ORE BY MOVEMENT CATEGORIES

(000,000 ton-miles)

From (To) To (From)	Quebec Ontario	Manitoba Ontario	U.S.A. Ontario	Ontario Ontario
1963	191	-	46	1,230
1964	301	-	38	1,349
1965	263	-	138	1,329
1966	146	15	138	1,245
1967	157	-	186	1,302
1968	61	5	167	1,546
1969	208	8	196	1,302
1970	236	8	152	1,435
1971	182	14	245	1,345
1972	177	10	103	1,811

TABLE III-37

MARINE FREIGHT OUTPUT FOR IRON ORE BY MOVEMENT CATEGORIES

(000,000 ton-miles)

From:	St. Lawrence	U.S. Great Lakes	Ontario	Ontario
To:	Ontario	Ontario	U.S. Great Lakes	Ontario
1963	58	4,854	2,287	270
1964	21	4,591	2,825	432
1965	406	3,870	2,365	535
1966	825	3,827	2,157	461
1967	1,071	2,190	2,220	635
1968	1,150	2,187	2,397	1,186
1969	692	1,979	2,353	1,456
1970	1,054	1,915	2,440	2,062
1971	1,198	1,200	2,078	1,912
1972	916	1,421	2,248	1,884

(d) Transportation Output - Forest Products

Table III-38 summarizes transportation output and modal shares for forest products for the period 1963 to 1972. Output volumes for each movement category are listed in Tables III-39 for the rail mode. A tabulation of marine mode volumes by movement category has not been included as the total volume was considered relatively insignificant, and over 80 percent of the movements were to U.S. Great Lakes ports. Structure of this section parallels the preceding section on grains.

(e) Transportation Output - Natural Gas

It is not possible to treat pipeline movements of natural gas in a similar manner to that used for rail and marine mode movements of solid commodities. Historical data does not permit compilation of a meaningful output series for a single province on a ton-mile or Mcf-mile basis. In considering the Ontario situation it was decided that the best approach would be to determine throughput in Trans Canada PipeLine's (TCPL) northern Ontario line. If destination patterns are relatively constant within and to the east and south of Ontario, a reasonable forecast of future pipeline system energy requirements should be possible. If changes in destination patterns are postulated, adjustment may be made as required to compensate for changes in the pipeline system. For the purpose of this analysis it is assumed that all natural gas used in Ontario or flowing through Ontario is supplied from outside the province in TCPL or Great Lakes Gas Transmission Company (GLGT) systems; minor levels of production within Ontario are ignored.

TABLE III-38

FREIGHT OUTPUT AND MODAL SHARES FOR FOREST PRODUCTS, ONTARIO

(000,000 ton-miles)

	Output			Percentage Share	
Year	Rail	Marine	Total	Rail	Marine
1963	1,636	209	1,845	89	11
1964	1,923	216	2,139	90	10
1965	1,875	201	2,076	90	10
1966	1,872	236	2,108	89	11
1967	1,993	213	2,206	90	10
1968	1,971	200	2,171	91	9
1969	2,115	272	2,387	89	11
1970	1,978	262	2,240	88	12
1971	2,208	240	2,448	90	10
1972	2,626	227	2,853	92	8

TABLE III-39

RAIL FREIGHT OUTPUT FOR FOREST PRODUCTS BY MOVEMENT CATEGORY

(000,000 ton-miles)

From (To) To (From)	Manitoba Ontario	Ontario Quebec	Ontario U.S.A.	Ontario Ontario	Manitoba Quebec
1963	299	245	622	337	133
1964	555	256	656	286	171
1965	423	275	644	365	168
1966	418	248	672	347	187
1967	496	328	644	321	204
1968	412	306	712	325	216
1969	572	374	736	232	201
1970	557	331	694	203	193
1971	608	347	621	381	251
1972	720	457	696	507	246

Table III-40 summarizes derivation of a series for throughput in TransCanada PipeLine's northern Ontario pipeline. The process of derivation requires aggregation of TCPL natural gas and transportation service sales in Ontario, Quebec, New York, and Vermont (III-35). From this sum, Canadian deliveries from GLGT are deducted to give the northern Ontario pipeline throughput.

TABLE III-40

DERIVATION OF THROUGHPUT, TRANSCANADA PIPELINES
NORTHERN ONTARIO LINE
(MMcf)

	1970	1971	1972	1973	1974	1975
SALES TO:						
Ontario	405,165	422,369	524,509	610,970	648,713	655,377
Quebec	48,729	50,171	53,962	59,801	71,171	68,876
New York	33,638	28,789	5,899	5,547	5,556	5,497
Vermont	2,532	2,820	3,745	3,912	4,891	4,124
TRANSPORTATION:						
Total Service	-	-	-	-	1,077	11,151
GREAT LAKES GAS TRANSMISSION:						
Canadian Deliveries	150,000 est	241,100	302,500	314,000	294,000	287,350
TRANSCANADA PIPELINES:						
Northern Ontario Throughput	240,064	263,049	285,615	366,230	437,408	457,675

(f) Transportation Output - Oil

Table III-41 summarizes transportation output of oil pipelines in Ontario. In calculation of the series it was necessary to assume that average load factor and efficiency of the Ontario system are equal to national averages. Annual outputs were calculated as the product of national barrel-miles multiplied by the ratio of Ontario pumping capacity to national pumping capacity (III-36).

TABLE III-41

OIL PIPELINE OUTPUT, ONTARIO

(000,000)

Year	Ontario HP / national HP	Barrel-miles	Ton-miles
1966	0.1356	30,934	4,652
1967	0.1427	36,397	5,473
1968	0.1267	35,796	5,883
1969	0,1381	44,189	6,645
1970	0.1442	53,031	7,975
1971	0.1129	45,364	6,822
1972	0.1051	50,215	7,551
1973	0.1004	56,032	8,426
1974	0.1103	59,024	8,876

(6.65 barrel-miles = 1.00 ton-mile)

The procedure used to calculate oil pipeline output takes no account of major expansion of pumping capacity. Expansion within Ontario would raise the value of the ratio of Ontario capacity to national capacity; expansion outside the province

would reduce the ratio. In order to determine the magnitude of this problem, Ontario deliveries were compared to national deliveries (III-37). If changes in the latter ratio correlate well to changes in the pumping capacity ratio it could be assumed that uneven expansion of pumping capacity would not result in erroneous output determinations. It was found that there was correlation in the direction of changes in the ratios between 1970 and 1974, and good correlation in the magnitude of changes between 1971 and 1974. Thus, the 1971 to 1974 output series is considered a suitable basis for forecasting of future output.

3. Historical Energy Use

3.1 Rail

Calculation of an energy intensiveness factor for the rail mode is discussed in the section on General Class Freight (A. 4.1 (b) Rail Mode - Historical Energy Use). There appears to be no statistical or practical basis for differentiation of energy intensiveness between General Class and Specified Class rail freight services. Thus, the Btu's per ton-mile series of Table III-22 is applicable to Specified Class rail freight. For a base case forecast, an energy intensiveness factor may be calculated from the equation:

$$EI = 24{,}368 - 12.03\ Y$$

where EI is the energy intensiveness in Btu's per ton-mile and Y is the year.

3.2 Marine

Calculation of an energy intensiveness factor for the marine mode is discussed in the section of General Class freight (A. 4.2 (b) Marine Mode - Historical Energy Use). There appears to be no statistical or practical basis for differentiation of energy intensiveness between General Class and Specified marine freight services. For the base year of a base case forecast, an energy intensiveness factor may be calculated from the equation:

$$EI = 17{,}605 - 8.67\ Y$$

where EI is the energy intensiveness in Btu's per ton-mile and Y is the year.

3.3 Natural Gas Pipelines

Table III-42 shows natural gas used in the Ontario pipeline system as a percentage of throughput in the TCPL northern Ontario line (III-31). While this type of factor is far from ideal, there appears to be no better source of data on energy consumption within the Ontario system. The factor excludes electrical energy consumption at the Bowmanville, Cobourg, Belleville, Kingston, Brockville and Cornwall TCPL compressor stations. The omission is minor; if a uniform load factor is assumed, electrical energy would account for less than three percent of compression energy consumed in 1974 (III-38).

TABLE III-42

PIPELINE TRANSMISSION NATURAL GAS CONSUMPTION, ONTARIO

Year	Throughput (MMcf)	Gas Used In System (MMcf)	Percentage of Throughput
1970	240,064	33,231	13.8
1971	263,049	36,310	13.8
1972	285,615	34,173	12.0
1973	366,230	26,640	7.3
1974	437,408	23,167	5.2
1975	457,675	na	-

Between 1972 and 1974 there appears to have been a major improvement in energy efficiency. It is believed that this change resulted, at least in part, from increased capacity of the TCPL system between Winnipeg and Toronto. A 36-inch looping project was completed in late 1972, and its operation in 1973 would have been expected to bring a significant increase in efficiency. In a pipeline system with increasing

throughput and periodic expansion of the system, it may be assumed that average efficiency will fluctuate from a low as the system reaches capacity to a high as a new expansion project is completed. Thus, the TCPL northern Ontario line should have been operating near minimum efficiency in the early 1970's and near maximum efficiency in the mid-1970's.

For forecasting purposes it is necessary to establish an assumed typical ratio of gas used in the system to throughput. For the transmission of gas into and through Ontario with a stable marketing pattern, nine percent should be a suitable ratio. In the event that a mileage figure is required it could be assumed that the average distance in Ontario is 1,150 miles.

3.4 Oil Pipelines

Table III-43 summarizes energy consumption, and energy intensiveness of oil pipelines in Ontario. As there is no source of statistical data on oil pipeline energy consumption, it was necessary to devise a procedure for determination of the series. To do this, it was assumed that annual energy consumption would equal the product of pumping horsepower, an efficiency factor for electric motor pumps, and load factor. As a proxy for provincial load factor, the national load factor for Interprovincial Pipeline Limited was used (III-39). Electric motor pumps were assumed to be 85 percent efficient. For forecasting purposes 260 Btu's per ton-mile is considered to be a suitable energy intensiveness factor.

TABLE III-43

OIL PIPELINE ENERGY CONSUMPTION, ONTARIO

	Horsepower	Load Factor	Kwh (000,000)	Btu's (000,000,000)	Btu's/ ton-mile
1966	41,450	na	-	-	-
1967	53,100	na	-	-	-
1968	53,600	na	-	-	-
1969	62,150	89.1%	425.7	1,453	219
1970	72,650	88.5%	494.3	1,687	211
1971	76,650	91.2%	537.4	1,834	268
1972	84,925	83.1%	542.5	1,851	245
1973	90,175	93.9%	651.0	2,221	263
1974	102,400	93.0%	732.1	2,498	281

4. Forecasting Methodology

The procedure for forecasting energy requirements for Specified Class Freight commodities includes the following steps:

(i) forecasting of transportation output for each Specified Class commodity;

(ii) calculation of modal output for each commodity on the basis of past or anticipated modal shares;

(iii) calculation of energy requirements to support the forecast modal outputs for each commodity on the basis of past or anticipated energy intensiveness factors;

(iv) aggregation of energy requirements for each mode for all commodities;

(v) calculation of fuel type requirements to meet modal energy demand on the basis of past or anticipated fuel type split;

(vi) aggregation of fuel requirements by type for both modes.

5. Sensitivity to Technological Change

5.1 Rail

Reference may be made to the General Class rail sensitivity section (III A 4.1 (c)).

5.2 Marine

Reference may be made to the General Class marine sensitivity section (III A 4.2 (c)).

5.3 Natural Gas Pipelines

Electrification of natural gas compressors presents a significant opportunity for both conservation and energy substitution. At the present time, most of Ontario's natural gas compression is derived from natural gas supplied from the pipeline itself. Natural gas is a suitable fuel for driving the various types of reciprocating and turbine engines which power compressor units. Efficiency of these engines range between approximately 24 and 38 percent (III-44).

Electric motors are quite suitable for driving gas compressors, and a few are, in fact, already in use in Onatrio. If an electric motor is assumed to be approximately 85 to 90 percent efficient, there is clearly a significant potential for reducing energy requirements to the pipeline itself. Whether or not there is a resultant saving in the total energy supply system depends on the source of electric energy. If the electricity is supplied from a thermal electric natural gas powered generating station with an efficiency of approximately 35 percent, there will be no saving of

consequence after line losses are taken into account. If, however, there is a requirement for additional natural gas, and if electricity can be supplied from a hydro, nuclear, or coal powered facility, a significant amount of natural gas can be added to the available supply through conversion of existing compressor engines, or through installation of electric powered compressors in new facilities.

Electrification of natural gas pipelines is a matter which requires co-operation between pipeline utilities, power utilities, and government. Pipeline companies will require large amounts of power, often at remote locations, and without penalization for frequent on-off cycles. Further, the supply must be absolutely reliable in order to ensure an uninterupted gas supply. The subject is one which merits considerable attention and investigation.

5.4 Oil Pipelines

It has not been possible to determine any technological changes which would have a significant effect on oil pipeline energy requirements. Energy intensiveness may be expected to fluctuate over a range as pipelines vary from low throughput (low energy intensiveness) to high throughput (high energy intensiveness). Construction of larger pipelines may be expected to slightly reduce overall energy intensiveness of the system.

C. URBAN TRUCK : FREIGHT AND NON-FREIGHT

1. Introduction

Urban trucking is composed of freight and non-freight components. The freight component includes pick-up and delivery trucks such as those operated by department stores, the Post Office, armoured security services, package delivery services, cement suppliers, etc. The non-freight component includes vehicles such as utilities' service trucks, contractors' and repairmen's trucks, and also personal urban use of vehicles which are registered as trucks and are used to a greater or lesser degree for passenger transportation.

Energy demand by urban trucking is forecast on the basis of forecast trucking output. For base case forecasting it may be assumed that recent levels of energy intensiveness will continue into the future. Subsequent to base case forecasting, the forecaster may change projections of socio-economic indicators and energy intensiveness and test sensitivity of energy requirements to these changes.

2. Transportation Demand

2.1 Historical Transportation Output

Table III-44 summarizes urban truck output in Ontario for the period 1955 to 1974. No Canadian statistics were available for derivation of the series. In the absence of the basic information, U.S. statistics were used to develop estimates of urban trucking output. A full explanation of sources and calculation procedures follows. Readers wishing to omit this section of the report may turn to Section 2.2 Explanatory Variables.

(i) Output statistics from the "1972 National Transportation Report" (III-45) were divided by U.S. urban population estimates (III-46) to produce ratios of urban truck output to urban population. Two types of trucking output were identified: urban freight and urban non-freight.*

(ii) Ratios of urban truck output to urban population were adjusted on a subjective basis to take account Ontario per capita incomes being approximately 10 percent below U.S. levels (Table III-45). These ratios, it should be noted, increase over time in the same relative pattern identified in the U.S. statistics. The increases in per capita output reflect, presumably, the greater dispersion of population and economic activity in urban areas and higher levels of disposable income.

* *In developing the urban non-freight estimates it was assumed that intercity non-freight vehicle-miles by truck (included) were equal to government urban truck vehicle-miles (not included).*

TABLE III-44

URBAN TRUCK OUTPUT, ONTARIO

Year	Freight (000,000 Ton-Miles)	Non-Freight (000,000 Vehicle-Miles)
1955	1,218	1,200
1956	1,309	1,309
1957	1,402	1,402
1958	1,499	1,520
1959	1,599	1,642
1960	1,724	1,769
1961	1,831	1,901
1962	1,963	2,059
1963	2,099	2,223
1964	2,215	2,368
1965	2,334	2,543
1966	2,482	2,725
1967	2,636	2,914
1968	2,738	3,023
1969	2,841	3,134
1970	2,946	3,247
1971	3,053	3,361
1972	3,160	3,477
1973	3,302	3,626
1974	3,414	3,745

TABLE III-45

URBAN TRUCK OUTPUT PER URBAN PERSON, ONTARIO

Year	Freight (Ton-Miles)	Non-Freight (Vehicle-Miles)
1955	330	325
1956	340	340
1957	350	350
1958	360	365
1959	370	380
1960	385	395
1961	395	410
1962	410	430
1963	425	450
1964	435	465
1965	445	485
1966	460	505
1967	475	525
1968	480	530
1969	485	535
1970	490	540
1971	495	545
1972	500	550
1973	510	560
1974	515	565

(iii) Urban population* estimates for Ontario for census years (1956, 1961, 1966, 1971) were used as a basis for interpolation of urban population for all years from 1955 to 1974. When multiplied by the urban person output ratios the output estimates shown in Table III-44 were produced.

There is no way of making direct checks on the accuracy of urban trucking output estimates. A number of indirect cross-checks were made, and are described below.

(i) U.S. Census of Transportation estimates for "local" operation of trucks in Michigan in 1972 (III-47) were compared with Ontario urban truck vehicle-miles. Using an average load of 2.3 tons for freight trucks, and allowing for difference in population and income levels, the Ontario urban truck vehicle-miles (freight and non-freight) estimate of 4,851 million appears to be reasonably consistent with the Michigan figure of 5,932 million truck-miles.

(ii) The 1974 Ontario truck fleet comprised 552,000 trucks. It is possible to "assign" these trucks to urban freight, urban non-freight, and inter-city operations, recognizing that individual trucks in fact may engage in more than one type of service. We are dealing, then with "truck equivalents".

* *Urban population was defined according to the Statistics Canada definition with the population cut-off at 2,500. This choice was primarily made in the interests of consistency with the U.S. data but it should not violate the a priori conception of urban truck operating conditions to any significant degree.*

urban freight	-	3,414 million ton-miles; 10,000 miles per year per truck, 2.3 tons average load. Truck equivalent requirement is 148,435.
urban non-freight	-	3,745 million vehicle-miles; 15,000 miles per year per truck. Truck equivalent requirement is 249,667.
intercity	-	the residual from 552,000 total Ontario truck registrations is 153,898. To produce output of 17,102 million ton-miles (Table III-1) with an average load of 3.58 tons* would require 30,410 miles annually from each of these "truck equivalents". This is high, but not unreasonably so.

(iii) The fuel required for 5,229 million vehicle-miles can be compared to total fuel use statistics for gasoline and diesel to determine if this size of urban truck fuel requirement is inconsistent with the quantity of fuel apparently used in this type of transportation. At an average of 11.7 miles per gallon (a weighted average calculated on the basis of 1974 output, and assumed energy intensiveness and fuel type split), 447 million gallons of gasoline and diesel oil would be required for urban truck transportation.

* *This is a ton-mile per vehicle-mile estimate using G.V.W. class shares for 1974 extrapolated from 1965-70 changes.*

(iv) Urban freight truck output estimates were published from 1956 to 1964 (III-48). The reliability of this source is suspect, but it does provide one set of published statistics for comparative purposes. The ton-mile estimates from this source compare poorly with ton-mile estimates in Table III-44. When, however, the average load in the SC series is adjusted to a more realistic 2.3 tons from the very long range of 1.2 to 1.4 tons, the difference between the two series are narrowed considerably.

2.2 Explanatory Variables

Although the urban freight sector has been divided into two sub-sectors, freight and non-freight, the factors affecting each are very similar. No surprises will be encountered with respect to either the types of variables or the specific series employed. Data relating to trucking in general, and to urban trucking in particular, is of extremely poor quality, and this has made a more specific selection of variables impossible. The variables which were selected for development of regression equations are shown in Table III-46, and a brief description of each follows.

(i) Transportation price index in Canada has proved impossible to obtain. As a proxy, therefore, the previously compiled index of the price of inter-city trucking* was deflated on the basis of changes in the Canadian wholesale price index. It was hoped that it might prove possible to reweight this series for specific years - using, for example, the "Canadian Urban Trucking Study" (III-49), which indicates that wage costs are probably more important for urban

* *Based on U.S. estimates collected by the Interstate Commerce Commission.*

TABLE III-46

INDEPENDENT VARIABLES

URBAN TRUCKING TRANSPORTATION DEMAND

YEAR	(1) PDY	(2) TPI	(3) SUB	(4) GPP	(5) URB
	$000,000		% x 10	$00,000,000	% x 10
1955	8,013	98	418	107	596
1956	9,002	98	430	119	600
1957	9,503	100	442	126	604
1958	9,944	101	454	124	608
1959	10,353	101	466	129	612
1960	10,593	101	478	133	616
1961	10,720	100	490	138	619
1962	11,430	99	498	146	623
1963	12,008	97	506	156	627
1964	12,566	100	514	169	631
1965	13,378	96	522	182	635
1966	14,203	90	530	197	646
1967	14,998	93	538	206	649
1968	15,805	95	546	220	653
1969	16,677	95	554	237	657
1970	17,430	97	562	250	658
1971	18,811	102	570	265	658
1972	20,203	96	578	285	658
1973	21,269	81	585	305	654
1974	22,372	72	592	324	650

(1) Real personal disposable income

(2) Transportation price index.

(3) Suburbanization index.

(4) Gross provincial product, deflated.

(5) Urbanization ratio.

shipments - but this has not been done due to the present lack of reliable historical data.

(ii) Suburbanization ratios remain a useful approximation of spatial changes in the distribution of the Ontario urban population.

(iii) Real gross provincial product (OS, Table 11.1) is used to explain the changes in the demand for freight trucking, whereas,

(iv) Real personal disposable income for Ontario was felt to be more appropriate to the non-freight sector,

(v) Urbanization ratio, expressing the percentage of the population of Ontario living in the CMA's, was found to be a useful characteristic variable.

2.3 Forecasting Model

(a) Introduction

The variables used in the equation for the two urban trucking sub-sectors, as shown in Table III-46, are identical except for the inclusion in the freight model of a production variable (GPP), while the non-freight sub-sector includes a provincial income variable (PDY). Both models are presented as ordinary least squares equations, although two stage estimation procedures were also tried.

(b) Discussion of Results

The equations shown in Table III-47 are quite successful in explaining historical variations in the output series. All variables are significant and of the right signs, and the Durbin-Watson statistics indicate that no severe auto-regression is present.

The large coefficient on the suburbanization index in the freight equation is surprising, as it indicates that, at a mean, an increase of 0.1 percent in the ratio results in a demand for an additional 5.7 million ton-miles of urban freight transport. The suburbanization index remains strong in the non-freight sub-sector, and the coefficient on price remains significant - a finding that might not be expected following the results of earlier tests in the inter-city and urban passenger sectors. Real personal disposable income, as would be expected, has considerable influence in explaining changes in non-freight demand, as does gross provincial product in the freight equation.

TABLE III-47

INITIAL REGRESSION MODEL : TRANSPORT DEMAND, URBAN TRUCKING

General Form of the Transportation Demand Model:

TRD_f = f (GPP, TPI, SUB, URB)

TRD_{nf} = f (PDY, TPI, SUB, URB)

where

TRD = urban truck transportation demand, freight (in millions of ton-miles) or non-freight (in millions of vehicle-miles)

PDY = personal disposable income, Ontario

TPI = transportation price index

SUB = suburbanization ratio

URB = urbanization ratio

GPP = gross provincial product

Basic Equation : Freight

TRD_f =	a_0 +	a_1(SUB) +	a_2(URB) +	a_3(TPI) +	a_4(GPP)
	-5575	57.3	72.1	-3.30	35.5
	(-11.57)	(8.85)**	(5.77)**	(-2.51)**	(10.77)**

R^2 = 0.999
F = 3723
DW = 1.53

Cont'd.

TABLE III-47 (Cont'd.)

Basic Equation : Non-freight

TRD_{nf} =	a_0 +	$a_1(SUB)_t$ +	$a_2(URB)_t$ +	$a_3(TPI)_t$ +	$a_4(PDY)_t$
	-9255	40.8	148.4	-6.95	0.06
	(-12.25)	(3.60)**	(7.46)**	(-3.48)**	(7.19)**

R^2 = 0.998

F = 2073

DW = 1.37

* *Significant at 0.10 percent level*

** *Significant at 0.05 percent level*

3.0 Energy Requirements

3.1 Historical Energy Use

Fuel Consumption is estimated as 14,920 Btu's per mile (10.0 miles per gallon) for gasoline powered freight trucks. 35,053 Btu's per mile (4.75 miles per gallon) per diesel powered freight trucks, and 11,477 Btu's per mile (13.0 miles per gallon) for non-freight trucks for the period of the early to mid 1970's. As the estimate is subjective there is no apparent value in attempting to establish energy intensiveness factors for less recent years. The high energy intensiveness of diesel trucks relative to gasoline trucks is because of a predominance of large and heavy vehicles in the diesel fleet. In a comparison between diesel and gasoline vehicles providing identical types and levels of service, the diesel vehicles could be expected to be considerably more energy efficient.

It is not possible to derive a direct relationship between historical trucking output and energy consumption data, as there is no source of suitable data. Published "road transportation" energy consumption data represent sales to "commercial transportation" and from "retail pumps". but fail to include industrial and government road fuel (III-26). User consumption data include non-transportation related energy use (III-25). Many assumptions would be required to allocate portions of user consumption to road use, and to split assumed road use quantities between automobiles and trucks. Subsequently, the assumed truck portion would have to be split between urban and inter-city trucking and the urban portion between freight and non-freight categories. The level of uncertainty inherent in results obtained from a procedure involving this number of assumptions reduces it to

one which, at best, might be used as a check on conclusions derived through some other procedure. The procedure used to relate energy consumption to urban trucking involves determination of vehicle miles, and assumption of the diesel vehicle to gasoline vehicle mileage ratio, and average energy intensiveness for the two urban trucking sectors. To gain a "feel" for typical energy intensiveness of various types of urban trucks, a brief telephone survey was conducted in Vancouver, British Columbia (III-50). Contact was established with fleet managers (or equivalent) of a number of firms with major trucking operations. All contacts were helpful, and detailed records maintained by most firms could be related to questions on mileage per gallon, average annual mileage, typical loads, vehicle life, major overhaul scheduling, and fuel types. On the basis of the survey, typical mileage per gallon for various vehicle sizes and operations is presented in Table III-48. It must be recognized that energy intensiveness for urban trucking is not solely a function of mileage driven. Large portions of total energy use may be accounted for by idling in congested traffic or during pick-ups and deliveries, and in operation of truck accessories including equipment such as hoists, lifts, pumps, compactors, auxilliary motor drives, etc.

TABLE III-48

TYPICAL MILEAGE PER GALLON FOR URBAN TRUCKING OPERATIONS

Size and Operation	Gasoline miles/gallon	Diesel miles/gallon
compact to sub-compact service wagon	20	
light delivery van, service van, pick-up (6 cylinder)	15	
light delivery van, service van, pick-up (8 cylinder)	12	
walk-in delivery van, ± 1 ton service van	9	
furniture van, heavy duty service truck, flat deck	5	
garbage truck, dump truck	4	6
tractor with semi-trailer		4.5
maximum size ready-mix cement truck		3.5

Urban trucking output in miles may be calculated from Table III-44. Non-freight trucking in 1974 accounts for 3,745 million vehicle-miles; using an average load of 2.3 tons, urban freight accounts for 1,484 million vehicle-miles. It is assumed that all urban non-freight trucks are gasoline powered (exceptions being insignificant) and that 70 percent of urban freight truck mileage is in gasoline powered vehicles. Current fuel consumption ratios are estimated at 10.0 miles per gallon for gasoline powered freight trucks, 4.75 miles per gallon for diesel powered freight trucks, and 13.0 miles per gallon for non-freight truck. Mileage and fuel consumption for 1974 are summarized in Table III-49.

TABLE III-49

URBAN TRUCKING MILEAGE AND ENERGY CONSUMPTION, 1974

Category	Millions of Miles	Millions of Gallons
Urban freight		
gasoline powered trucks (70%)	1,039	104
diesel powered trucks (30%)	445	94
Urban non-freight		
gasoline powered trucks	3,745	288

3.2 Forecasting Methodology

Demand for urban freight and urban non-freight trucking may be forecast on the basis of correlation to predicted or potential trends in the socio-economic explanatory variables used in the historical correlation analysis. A base case energy forecast may be developed using mid-1975 fuel efficiencies: 14,920 Btu's per mile for gasoline powered freight trucks, 35,053 Btu's per mile for diesel powered freight trucks, and 11,477 Btu's per ton-mile for non-freight trucks.

3.3 Energy Sensitivity

In general, it is more difficult to postulate changes in urban trucking which will affect energy consumption than was the case for inter-city trucking. Changes may be considered to fall within three broad categories: technological, operational and those related to the urban infrastructure. Many of the technological options available in trucking will be inconsequential to energy consumption of trucks operating at urban speeds and in urban congestion. Operational changes could result in relatively minor changes in energy intensiveness; however, without surveys, their overall impact cannot be predicted. Changes in urban infrastructure could bring changes in energy intensiveness; however, positive changes would generally require complex planning and major cost.

(a) Technological Options

(i) Gasoline to diesel conversion of small trucks: Documentation of experimentation is quite limited, and availability of small diesel engines and servicing facilities is a problem. One report indicates that under various urban driving conditions a diesel equipped truck gave approximately double the mileage per gallon of similar gasoline truck operations on the same routes (III-51, 56). Also, idling diesels require only about one-quarter the fuel volume of idling gasoline engines. It is apparent that availability of small diesel vans at competitive costs, and with adequate service facilities, could have a major impact on reduction of energy demand for urban trucking.

(ii) Radial tires: The impact of radial tires on energy consumption is subject to controversy and the suggested magnitude of potential energy savings varies between different reports from close to zero to several percent. Test programs appear to be justified.

(iii) Reduction of truck weight and engine power: Only a small portion of urban trucks are loaded to gross capacity. Development of light weight vehicles with required volume capacity would allow reduction of engine power for similar performance. Reduction of power with a corresponding reduction in performance might also be considered for a significant portion of the urban fleet. While the results may not be directly applicable, it is interesting to note considerable interest amongst inter-city truckers in reducing tractor power and offsetting the power reduction with other changes in the fuel feed and drive. Energy conservation is being achieved in this manner.

(iv) Wind resistance: It is unlikely that changes in urban truck acrodynamics would result in meaningful changes in energy intensiveness. Air resistance is not a significant factor at typical urban speeds.

(b) Operational Changes

(i) Engine turn-off: Elimination of idling during pick-ups, deliveries and service calls would reduce total energy consumption, though the magnitude of

potential savings would require knowledge of present idling patterns. A typical urban truck is believed to use slightly less than a gallon of gasoline per hour of idling. Elimination of idling fuel would have to be offset against repeated surges of start-up fuel.

(ii) Improved maintenance: Rigid control over engine tuning, cleanliness of air filters, etc. maximizes fuel efficiency. Most truck operators with large fleets are well aware of this fact.

(iii) Consolidation of private trucking services: A number of companies provide their own private delivery service. Typically, these private carriers operate vehicles below capacity, and sometimes at only a small fraction of weight capacity. Consideration might be given to the energy impact resulting from consolidation of delivery services. If warranted, a change might be induced through some form of selective penalization of private freight carriers.

(c) Urban Infrastructure

(i) Staging points: Urban operation frequently involves a relatively short period of filling a truck to capacity or emptying it from capacity, followed by a relatively lengthy round trip to a base. Servicing of staging points by maximum-size trucks could eliminate the repeated round trips to a distant base to pick-up or deliver a load.

(ii) Improved traffic flows: Reduction of deviations from average speed and repeated stops in traffic congestion would improve the output per vehicle. The cause is

more easily recognizable than the solution. From a trucker's viewpoint, trucking lanes in congested areas of the larger cities would be very desirable. Careful attention to traffic light synchronization in the direction of traffic flow, and in certain cases provision of synchronization in opposite directions on nearby parallel arterial streets, are procedures which can reduce variations in vehicle speed. The magnitude of potential energy savings can be predicted from detailed studies of specific situations.

IV OTHER TRANSPORTATION SECTORS

1. General Aviation

Use of fuel by general aviation is not included in the previous inter-city air mode analysis. Passenger mile output data are not available. Historical fuel use figures for 1965 to 1974 are available for Ontario for the category "General Flying and Other" (Table IV-1). Fuel use by this category of demand has ranged from 7 to 12 percent of the Ontario fuel consumed by commercial carriers over the period 1965 to 1974 (Table IV-2). It is suggested that a ratio of 8 percent be assumed to remain constant over the forecast period and that this be used as the basis for predicting future fuel use in this market. Approximately two-thirds of energy requirements are derived from aviation gasoline and one-third from aviation turbo fuel.

2. Federal and Provincial Government Transportation

(i) Aviation Fuel Use

Federal and Provincial government use of aviation fuels ranged from 6 to 24 percent of commercial carrier use over the 10 year period 1965 to 1974 (Table IV-2). As in the case of the General Flying category a historically derived ratio of fuel use by this category compared to commercial carrier use is suggested as the basis of estimating future fuel demand. A ratio of 10 percent is recommended based on the experience from 1969 to

TABLE IV-1

AIRCRAFT FUEL USE FOR "GENERAL FLYING" AND
BY "FEDERAL AND PROVINCIAL GOVERNMENTS"

ONTARIO, 1965 - 1974

(000 barrels)

	Aviation Turbo Fuel			Aviation Gasoline		
	Gen.(1) Flying & Other	Fed.& Prov.(2) Gov't.	Total	Gen.(1) Flying & Other	Fed.& Prov. Gov't.	Total
1965	42	353	395	106	85	191
1966	68	289	557	157	67	224
1967	107	373	480	166	61	227
1968	145	153	298	171	58	229
1969	259	234	493	179	55	324
1970	101	440	541	168	31	199
1971	99	430	529	196	27	223
1972	107	473	581	203	19	222
1973	131	512	643	244	20	264
1974	210	523	733	297	20	317

SOURCE: 1965 to 1974 SC 45-208.

(1) "General flying and other" fuel use is a balancing category; it is the difference between total fuel "available for distribution" in Ontario and that accounted for by sales to the following four categories:

Canadian airlines
Foreign airlines
Foreign governments
Federal and provincial governments

(2) Federal and provincial government use includes uses by the Canadian Armed Forces & Federal and provincial police forces.

TABLE IV-2

AIRCRAFT FUEL USE FOR "GENERAL FLYING" AND BY "FEDERAL AND PROVINCIAL GOVERNMENTS" AS A PROPORTION OF TOTAL AIR FUEL

ONTARIO, 1965 - 1974

(000 bbls)

Year	Commercial Carriers Fuel Use	Commercial Carriers % Total	Fed. & Prov. Governments Fuel Use	Fed. & Prov. Governments % Comm	General Flying and other Fuel Use	General Flying and other % Comm	Total Air Fuel
1965	1,837	76	438	24	143	8	2,423
1966	2,287	80	356	16	225	10	2,868
1967	2,803	80	434	15	273	10	3,510
1968	3,314	86	211	6	316	10	3,841
1969	3,570	83	289	8	438	12	4,297
1970	4,110	85	471	11	269	7	4,850
1971	4,189	85	457	11	295	7	4,941
1972	4,388	85	492	11	310	7	5,190
1973	5,143	85	532	10	375	7	6,050
1974	6,113	85	543	9	507	8	5,163

SOURCE: Tables II-58, II-66.

1974. The proportion of aviation gas to total fuel has declined from under 20 percent to 3.6 percent and is likely to continue to decline both from the relative increase in the turbo aircraft proportion of government aircraft, and from the removal from service of older, piston driven aircraft.

(ii) Highway Use

Highway vehicle use of fuels by Federal or Provincial government trucks or automobiles is included in appropriate passenger and freight sectors as detailed in Chapters II and III.

3. Military Transportation

Available data does not allow accurate identification of military transportation output and fuel use. Findings on military transportation and comments on military energy forecasting are listed below.

(i) Road transportation

Military vehicles are not generally included in provincial motor vehicle registration data; however, there are exceptions in the case of military automobiles which bear provincial license plates. As energy demand for motor vehicles is forecast on a vehicle basis, military vehicles which do not bear Ontario license plates will be excluded from forecasts. The quantity of fuel use by these vehicles would be very small in relationship to total road fuel, and an attempt to accurately identify historical levels of fuel use and predict future fuel demand does not appear to be warranted.

(ii) Air transportation

Military use of aviation fuels is included in the "federal and provincial governments" fuel use category (II-19). Forecasting future military demand for aviation fuels is therefore an integral part of the forecasting process for government demand.

(iii) Marine transportation

Military marine transportation output and energy use are both excluded from the data sources which have been used. Considering the level of naval activity on the Great Lakes it is considered unnecessary to attempt to forecast military marine fuel requirements in Ontario.

4. Motorcycles

Motorcycles account for a very small proportion of total transportation energy consumption. In 1974 there were 68,420 motorcycles registered in Ontario. It is assumed that the large majority of these vehicles have small engines and receive quite limited use, while a small minority have relatively large engines and have levels of use approximately in line with average passenger automobiles. It is estimated that average fuel use per motorcycle is 40 gallons per year, or a fleet total of 78,194 barrels per year. All of this fuel would be gasoline.

Future motorcycle fuel requirements will remain as an insignificant proportion of total transportation fuel, unless a major substitution of motorcycles for urban passenger automobiles can be achieved. Serious consideration of this possibility does not appear to be justified after taking winter conditions into account. Therefore, a suitable base case annual growth rate for motorcycle fuel requirements is estimated as 4.0 percent.

5. School Buses

Approximately 6,500 school buses were operated in Ontario during 1974. It is believed that the following estimates are

reasonable for operating parameters:

- an average of 10,000 miles per vehicle annually;
- an average of 7.0 miles per gallon;
- energy derived from gasoline.

On this basis, approximately 265,000 barrels of gasoline would have been consumed in 1974.

For forecasting purposes it is recommended that the approximate 1974 fuel consumption figure be increased at the rate of 1.2 percent per annum; the projected rate of growth of Ontario's population. While the forecast could be refined through introduction of considerations of age structure and rural proportion of the population, the relatively small amount of fuel involved (0.35 percent of gasoline sales) does not appear to justify additional study at this time.

6. Leisure Related Transportation

A minor transportation fuel use category relates to leisure transportation including boating and snowmobiling.

In the spring of 1974 the number of motorboats in Ontario was reported at 217,000 and the number of snowmobiles at over 312,000 (II-20). No fuel use statistics for these classes of use are reported. Order of magnitude estimates for 1974 are 200,000 barrels of gasoline for snowmobiles* and 620,000 barrels of gasoline for power boats.**

Forecasts of fuel use for these categories are difficult

* *1,000 mi/veh X 50 MPG X 312,000 = 178,000 bbls.*

** *1,000 mi/boat X 10 MPG X 217,000 = 620,000 bbls.*

to estimate. It could be argued that snowmobile fuel use will remain static; power boat fuel uses could be estimated to increase at approximately the estimated future rate of increase of real personal disposable income of 4.0 percent per year.

V OPPORTUNITIES FOR DATA IMPROVEMENT

Historical data regarding transportation output and energy and fuel consumption were found to be of generally poor quality. Similarly, it was found that data were inadequate for optional compilation of series of explanatory variables. Considerable effort would appear to be warranted in improving and supplementing the historical data base. Also, perhaps more important, action is required to establish data collection programs in which current and future information will be collected in order to facilitate expansion and continuous updating of the data base.

An exhaustive list of specific recommendations of existing data and collection of additional data follow. Recommendations are in point form, referenced by page, to the portions of Chapter II to IV to which they apply.

A. INTER-CITY PASSENGER SECTOR

(i) Historical motor vehicle registration figures for Ontario require further examination to determine if more precise estimates can be made of the average annual number of passenger automobiles operating in the province each calendar year. (page 10)

(ii) Future automobile registration figures for Ontario should be compiled by MTC by size class; for example, sub-compact, compact, intermediate, and standard. (page 10)

(iii) Automobile driver surveys are needed to determine:

- miles driven per year by category of trip purpose;
- load factors by trip purpose separated into urban and inter-city components. (page 11)

(iv) Further consideration should be given to a procedure for estimating the percentage of total automobile vehicle miles travelled in the inter-city and urban sectors. Two factors requiring specific attention are the definition of "urban" and "inter-city" driving, and the "split" assumptions. (page 11)

(v) The Aviation Statistics Centre of Statistics Canada should be requested to compile historical passenger mile totals for air routes within Ontario for both unit toll and charter services. Ontario legs of extra-provincial flights should be included as a disaggregated component. (page 15)

(vi) School bus registrations should continue to be compiled by SC or MTC. Estimates should be made of school bus passenger miles of service. (pages 19 and 260)

(vii) Checks should be made of the assumption that historically one-half of inter-city bus travel was made on class A highways and one-half on class B highways. Detailed discussions should be held with bus operators in Ontario to obtain better estimates of load factor and fuel use, and to discuss future technology and operating procedures. Urban charter bus information is also necessary with respect to annual passenger miles of output and fuel use. (page 21)

(viii) Negotiation of contracts with CN and CP should be considered for provision of historical and future railway passenger-mile and ton-mile output data. (page 22)

(ix) Explanatory variables describing service quality require considerable improvement before they can be used successfully as a basis for analysis. Information on factors such as frequency or dependability of service is presently unavailable. Information on trip purpose and average trip distance has not been collected at regular intervals. (page 41)

(x) Survival rates for automobiles in Ontario should be developed in co-operation with MTC. Automobile registration data should be collected and processed so that for each year the number of automobiles by age and by size class is known. Consideration should be given to probable changes in survival rates in the future. (page 51)

(xi) More thought needs to be given to developing actual automobile fuel efficiency ratios specific to Ontario. Surveys should be undertaken in co-operation with the Federal Ministry of the Environment and the Office of Energy Conservation (EMR). Consideration should be given as to how gasoline and diesel oil sales could be identified by type of consumption (car or truck). (page 54)

(xii) Relationships need to be developed between fuel use efficiency and changes in automobile drag coefficients under various operating conditions. (page 60)

(xiii) A more detailed analysis is required to establish the effect of convenience devices such as air conditioners on fuel use efficiency. A survey of proportion of the stock of Ontario autos outfitted

with various convenience devices should be made, and updating of this data should be undertaken periodically. (page 62)

(xiv) Fuel efficiency ratios should be developed for a range of engine types which could be introduced in the future. The impact of these technologies on fuel use could then be evaluated. (page 65)

(xv) Surveys of air carriers operating in Ontario should be undertaken to obtain a better determination of historical and present load factors. Discussions should be held with Air Canada personnel and regional carriers to establish more precisely fuel use ratios by aircraft type, and possible fuel use improvements which could be achieved through changed ground and air operating procedures. (page 68)

(xvi) A better understanding is required with respect to types of aircraft operated by Group III, IV, and V carriers, and fuel use efficiencies experienced for typical stage lengths. More data needs to be gathered on typical load factors of these operations. Discussions should be held with Norontair. (page 68)

(xvii) Joint study with MTC is required to establish which routes in Ontario are travelled heavily enough to warrant electrified rail systems. It would then be necessary to establish load growth forecasts for these specific routes. Consideration should be given to whether high speed electric passenger systems such as one between Toronto and Montreal can co-exist with freight traffic or whether it is

necessary to dedicate a spearate right-of-way to passenger traffic. Discussions should be held with the Canadian Institute of Guided Ground Transport at Queens University, which has recently completed a major electrification analysis related to the Canadian rail system. (page 92)

B. URBAN PASSENGER SECTOR

(i) Further discussion should be held with MTC and Toronto Transit Commission personnel to improve estimates of total fare-paying passengers, transfer passengers, and average trip distances of passengers. Passenger surveys will probably be required to obtain good current data on these parameters.

Discussions of a similar nature should be held with GO-Transit officials. More information is required on ridership, average trip distance, fuel use patterns and future expansion plans. (page 100)

(ii) Better information is required concerning taxi operations in Ontario. Taxi operators should be interviewed or surveyed with respect to annual mileage per taxi, fuel use efficiencies, and passenger miles per vehicle-mile ratios. A better estimate of total taxis in Ontario is required and consideration should be given to identification of taxis in vehicle registration data. An assessment should be made of the potential value of disaggregating true taxis from other types of rental vehicles and if warranted, separate statistical data should be compiled. (page 106)

(iii) Discussions should be held with transit operators and the Urban Transit Development Corporation concerning future public transit technologies and possible impacts on energy use. (page 124)

C. EXTRAPROVINCIAL AIR PASSENGER SECTOR

(i) Departing passenger data require improvement and special

compilations by the Aviation Statistics Centre of SC should be considered. The subject of charter flight passenger departures and load factors requires investigation.

(ii) Air carriers and fuel supply companies should be interviewed to gain a better understanding of fuel lifting patterns of Canadian and foreign carriers. Specific attention should be given to factors which would cause more or less fuel to be lifted from Ontario versus other airports. (page 134)

(iii) A report prepared by the federal MOT concerning forecasts of air passenger traffic at Toronto should be obtained and compared to forecasts produced by the forecasting model developed in this report.*

D. GENERAL

(i) With respect to carrying out travel surveys to improve the data base, it would, in many cases be desirable to have these done at the national level by SC or the Ministry of Transport with Ontario representatives co-operating in the larger effort. The drawback would be the resulting delays in getting work started.

E. INTER-CITY GENERAL CLASS FREIGHT

(i) In comparison to other transportation output data, railway freight output data are of quite high quality.

* *Mr. R. Duclos, Forecasting Research, Toronto International Airport Project, Ministry of Transport, Ottawa.*

CTC flow data are an excellent basis for calculation of output (III-2), and representations should be made to encourage future updating of the series. Data in the series (as opposed to accompanying methodology) should be placed in the public domain. The basis for calculation of mileages for rail was a "one-time" survey (III-1), and though annual updating would be unwarranted, regular, periodic updating would be desirable (page 155).

(ii) Marine flow data are available from the same CTC source as rail data (III-2); however, there are noticeable errors, and the series are shorter. There is no published basis for direct access to mileages of marine freight movements, and the "one-time" compilation included in this study is not fully adequate for future use.

Consideration should be given to the ability of SC to improve data in the <u>Shipping Report</u> series and to the possibility of including estimated ton-miles of incoming and outgoing freight in the origin-destination data.(page 161)

(iii) Trucking output data are inadequate. Discussions should be held with SC and MTC to expand future data collection. The <u>SC For-hire Trucking Survey</u> warrants annual updating and improvement in survey techniques. Surveys are also required to estimate the output of private trucking and consideration should be given to their regular administration at weight scales and border crossings.(page 165)

(iv) Truck registration data by size class should be compiled

on an annual basis by MTC. Data should include identification of numbers of gasoline and diesel engines in each size class.(page 169)

(v) A measure of the average value of shipments or the value of shipments per ton would be a useful explanatory variable. Discussions should be held with MTC to consider surveys or other potential means of obtaining this type of data on a regular basis.(page 181)

(vi) Discussions should be held with CN and CP to determine the validity of the assumption that there is no net gain or loss of railway fuel across provincial and international boundaries. If the assumption is incorrect, an attempt should be made to estimate the net gain or net loss of fuel to Ontario.(page 168)

(vii) Railway energy consumption data should be disaggregated by SC for the freight and passenger sectors on a provincial basis.(page 187)

(viii) Discussions should be held with the major railway companies to determine specific reasons for historical reduction in energy intensiveness and to determine the probable future evolution of this trend.(page 190)

(ix) Present knowledge of marine fueling patterns and vessel energy intensiveness is inadequate and surveys should be undertaken by MTC or OME to improve and expand available information. Initially, contacts should be established with Great Lakes shipping companies and petroleum and coal suppliers.(page 193)

(x) Discussions should be held with major shipping companies to determine specific reasons for historical reduction of energy intensiveness and to determine the probable future evolution of this trend. (page 197)

(xi) Investigations should be undertaken to identify the present users of coal on the Great Lakes and to assess the probability of an ongoing requirement for coal. (page 200)

(xii) Studies should be undertaken in conjunction with the federal Office of Energy Conservation or MTC to determine the potential for marine fuel savings through use of fuel additives and marine engine and boiler attachments. (page 203)

(xiii) In conjunction with MTC, surveys should be considered to establish truck fuel consumption and type by weight class and to determine average annual inter-city and urban mileages by weight class. Data should also be collected on age structure of the truck fleet and scrappage rates. (page 204)

F. INTER-CITY SPECIFIED CLASS FREIGHT

(i) A request should be made to SC to disaggregate natural gas and oil pipeline output data on a provincial basis. To the extent possible, historical as well as future data should be included in this disaggregation. (pages 223 and 227)

(ii) Discussions should be held with CN and CP to determine if there is any significant difference in energy intensiveness between General Class and Specified Class rail freight.(page 229)

(iii) A request should be made to SC to positively identify natural gas pipeline energy consumption including both gas and electricity.(page 230)

(iv) A request should be made to SC to include energy consumption by oil pipelines on a provincially disaggregated basis in future oil pipeline statistics.(page 231)

(v) Representations to, and coordination of, discussion between Ontario Hydro and TransCanada Pipelines should be undertaken to determine the potential for energy savings and fuel substitution through electrification of pipeline compressors.(page 234)

G. URBAN TRUCK : FREIGHT AND NON-FREIGHT SECTOR

(i) Studies should be undertaken to improve definition of the freight and non-freight components of urban trucking to distinguish operating differences between the components and within the components by size class and type of operator.(page 236)

(ii) Consideration should be given to undertaking studies aimed at improving and updating estimates of urban freight and non-freight trucking output per urban person.(page 237)

(iii) In cooperation with MTC, consideration should be given to an expanded survey of commercial urban truck operating parameters in various Ontario cities. The brief survey conducted in Vancouver was considered quite successful and similar additional work would be useful in verifying and expanding the results. (page 249)

H. OTHER TRANSPORTATION SECTORS

(i) Surveys should be undertaken by MTC or OME to determine average annual fuel consumption per motorcycle. (page 260)

(ii) Surveys should be undertaken by the Department of Industry and Tourism or MOE to determine average annual fuel consumption per motor boat and per snowmobile.(page 261)

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